Appendix D: Supporting Documentation for Chapter III.

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Using Appendix D

The purpose of this appendix is to provide the detailed methods and supporting documentation that are the underpinnings of the main body of the report but too detailed or extensive to report there. This appendix provides background to the information contained in Chapter III of the main body of the report. Information is included in this appendix <u>only</u> if the authors believed that details needed to be documented.

Hydrologic Summaries for Subbasins

Black River/Springbrook Creek

Drainage Area: 17,031 acres (26.6 square miles).

Tributaries: Springbrook Creek flows into the Black River and enters the Green River at RM 11, through the Black River pump station. Tributaries include Mill, Garrison, and Panther Creek.

Hydrogeology: Mill Creek and other tributaries arise from the western edge of the Covington uplands drift plain, and cut canyons through the glacial deposits before emerging onto the valley floor. Recessional outwash deposits cover the floors of these side canyons. Advance outwash and pre-Fraser seepage zones are exposed at the base of the bluffs, and recharge the alluvial aquifer. Seepage in one side canyon feeds springs used for water supply by the City of Renton.

Small alluvial fans develop where the creeks transition onto the valley floor. The lower reaches of Mill Creek and most of Springbrook Creek flow through extensive alluvial deposits on the Green River valley floor.

Groundwater Recharge: Recessional outwash deposits cover 3.3 percent of the basin; 42 percent of these recharge areas are covered by impervious surfaces. HSPF modeling for the Green River WQA calculated a total annual recharge rate of 11 inches per year, with 13 inches year on till and 18 inches per year on outwash.

Soils: Till soils cover 39 percent of the basin. Outwash soils cover only 1.5 percent of the basin, but well-drained alluvium covers 17 percent. The USDA maps a large area (21 percent) of urban/modified soils.

Streamflow/Runoff Production: Mill, Garrison and other eastern tributaries arise from wetlands, lakes and rolling hills on the Covington drift plain, about 500 feet above the valley floor. Runoff in these till-covered areas is produced primarily as shallow subsurface interflow. Seepage zones along the valley wall bluffs contribute baseflow to streams and feed wetlands that line the upslope side of SR-167 along the base of the bluffs. The lower portion of the basin occupies a low-gradient alluvial floodplain on the Green valley floor. Fine-grained alluvial soils saturate quickly, but historically much of the annual runoff volume would have been captured by depressional wetlands on the valley floor. The watershed is now heavily urbanized, with an EIA of 25 percent estimated in the Green River WQA calibration report. Landsat data from 1998 show 12 percent forest and 58 percent TIA. Springbrook Creek has a mean annual flow of 40 cfs. Mill and Garrison Creek provide a combined mean annual flow of 29 cfs (Kerwin and Nelson, 2000).

The Black River pumping station is operated by King County. During floods the pumping station acts as a dam, preventing Green River flows from backwatering into the Black River. Water levels downstream of the pumping station range from –4.0 to +21.5 feet MSL, depending on tidal conditions and the water level of the Green River. Water surface elevations upstream of the pumping station are normally held in the range of 0.0 to 2.0 feet, but can reach as high as 13.0 feet. The pumping station consists of a series of eight pumps, and can pass flows of up to 2,945 cfs. During large floods inflows from Springbrook Creek exceed the capacity of the Black River pump station, resulting in backwater flooding upstream of the pumps (Kerwin and Nelson, 2000; King County FIS, 1989). Table D-1 contains flow estimates from King County.

Table D-1. Flow estimates for Black River Subbasin.

Location	Drainage Area (square miles)	10-year Peak Flow (cfs)	100-year Peak Flow (cfs)
Black River below pump station	24.8	400	400
Black River pump station inlet	24.8	650	1230
Springbrook Creek at Black River confluence	21.9	590	1100
Springbrook Creek below Mill Cr.	16.1	680	1055
Mill Creek at mouth	9.2	380	650
Mill Creek at SR 167	3.1	110	130

Source: FEMA, 1989

With the elimination of overbank flooding from the Green, flooding on the valley floor is now strongly driven by high groundwater levels in topographic depressions (FEMA, 1989). During floods the Green River is perched above groundwater, preventing subsurface drainage to the river. Perched ponds may also form in depressions that are lined with fine-grained soils.

A detailed HSPF model was developed and calibrated as part of the *Green River WQA study* (*King County and Aqua Terra Consultants, 2003*). The model used precipitation data from King County's Panther Lake rain gage, with a mean annual precipitation volume of 39 inches. The model was calibrated against streamflow data for two King County gages (Black River at Grady Way (03G) and Black River upstream of Mill Creek diversion structure (03F)) and three USGS gages (one on Springbrook River and two on Mill River). The model used 52 catchments ranging from 0.04 to 1.81 square miles in area. Extensive areas of alluvium were treated as either till (old alluvium) or outwash (recent alluvium). The model produced the overall water balance results for October 1998 – September 2002 that are shown in Table D-2. The model was also calibrated to simulate daily water quality, including temperature, DO, sediments, and various pollutants; plots are presented in the report.

Table D-2. Overall water balance results, Oct. 1998 to Sep. 2002.

Component	Till and Old Alluvium	Outwash and Recent Alluvium	EIA	Watershed Average
Precipitation	38.5	37.7	38.0	38.0
Surface Runoff	1.3	0.2	30.4	8.4
Interflow	7.2	2.9	0	3.8
Baseflow	12.4	17.6	0	10.8
Evapotranspiration	17.4	16.3	7.5	14.7
Deep GW Recharge	12.6	18.0	0	11.2

Note: All units are inches

Storage Features: Panther Lake is the largest headwater lake. Panther Creek flows down from the lake and through a series of wetlands along the base of the valley walls, upslope of SR 167. Depressional wetlands occupy undeveloped areas on the valley floor/historical floodplain. The Earthworks Park Detention Pond stores flood flows from upper Mill Creek. The Green River Natural Resources Area consists of a series of storage cells connected by adjustable weir structures that regulate outflow *(Green River WQA*). The Mill Creek diversion structure diverts flow from Mill Creek into the Green River Natural Resource Enhancement Area *(Green River WQA).*

Geomorphology: Tributary creeks begin on the Covington drift plain, and drop abruptly through steep canyons to the valley floor, where stream gradients are virtually flat. Stormwater runoff has caused streambank erosion, scouring and siltation in Mill, Garrison, and Springbrook Creeks(*WRIA 9 LF and Recon Report*). Severe streambed incision is occurring in Mill and Garrison Creeks. Upper reaches of Mill Creek used to flow through gravel bedded channels and wetlands, but are now channelized into a swale. Upstream of the Earthworks Park Detention Pond the channel enters a forested ravine and contains patches of gravel. The lower reaches of Mill Creek contain silts typical of low-gradient streams.

In upland areas Garrison Creek contains gravel mixed with silt, sand, and cobbles. Some tributaries also contain occasional boulders. Streambanks are made up of highly erodible alluvial soils. Once Garrison Creek enters the ravine, the channel substrate is dominated by gravel, cobble, and boulders. There were signs of erosion in this ravine during a 1993 habitat survey. The lower reaches of Garrison Creek contain heavily modified, low-gradient channels lined with silts and fine sands.

Lower Green East

Drainage Area: 4,787 acres (7.5 square miles).

Tributaries: Includes the Green mainstem and minor tributaries between Soos Creek and Mill Creek. Side canyon tributaries include Lea Hill Creek, Olson Creek, and Cobble Creek.

Hydrogeology: This reach of the Green flows through extensive alluvial deposits on the valley floor. Tributaries arise from the Covington upland drift plain, and cut steeply through ravines on the valley walls. Seepage zones line the eastern edge of the valley where bluffs have exposed advance outwash and pre Fraser deposits. A coarse-grained alluvial fan has developed where the Green and White enter the lower-gradient Auburn-Kent valley.

Groundwater Recharge: Recessional outwash deposits cover 11.6 percent of the basin; 53 percent of these recharge areas are covered by impervious surfaces.

Soils: Till soils cover 49 percent of the basin. The USDA maps a substantial area of urban/modified soils (29 percent). Outwash soils cover only seven percent of the basin.

Streamflow/Runoff Production: Runoff from till soils in tributary catchments is produced primarily as shallow subsurface interflow. The valley floor would historically have been inundated by floods from the Green River. Fine-grained alluvial soils saturate quickly, but historically much of the local runoff on the valley floor would have been captured by depressional wetlands. Landsat data from 1998 show 22 percent forest and 44 percent TIA.

In the early 1900s a log jam diverted the entire White River into the Puyallup through an overflow channel formerly called the Stuck River. A diversion structure was constructed in 1911 to keep the White River in this configuration. The loss of flow from the glacier-fed White reduced summer flows in the Green by about 50 percent (Kerwin and Nelson, 2000). Groundwater still flows from the White to the Green, contributing about 56 cfs to the lower Green in the late summer (Pacific Groundwater Group, 1999). Summer flows at Auburn are generally close to 250 cfs. Winter flows average about 1,500 to 2,000 cfs (Green WQA Scoping Document).

Urban development has substantially increased stormwater runoff from tributaries. This has increased peak winter flows, reduced recharge of shallow aquifers, and decreased dry season flows. The effects of increased runoff on the mainstem Green are secondary in comparison to flow regime changes caused by diversions, channel modifications, and operation of the Howard Hanson Dam, which limits flood flows in this reach to no more than 12,000 cfs.

Tributaries like Lea Hill and Olson Creeks arise from wetlands on the adjacent drift plains. Cobble Creek is fed primarily by surface runoff from the edges of the valley walls.

Storage Features: Large depressional wetland complexes once covered much of the lower Green Valley floor, and were fed by frequent flood flows, alluvial groundwater, and stormwater runoff. Remnants of these still exist, but no longer receive overbank flow from the Green. They still store runoff from tributary areas on the valley floor, and are fed by alluvial groundwater when water levels in the Green are high.

Geomorphology: The following review of channel morphology was taken from the WRIA 9 Limiting Factors and Reconnaissance Report: The diversion of the White River in 1906 dramatically reduced the supply of sediment to the lower Green. The White River once supplied 75 percent of the sediment to downstream reaches of the Green, although much of this was deposited in an alluvial fan at the historic mouth of the White that extended to about RM 27. The lower Green has responded to these changes by forming a new floodplain channel within the historic channel, with a new floodplain elevation at least 7-feet lower than the pre-diversion floodplain. Valley floor deposits downstream of the fan are mostly mode up of silt, clay, and fine sand interbedded with peat. About 90 percent of the once extensive floodplain is no longer inundated on a regular basis (*Green River WQA Scope Document*).

Levees and stream bank revetments affect over 80 percent of the length of channel between RM 25 and RM 31. Levees are virtually continuous along both banks downstream of RM 25.

Landslide and slope failures in tributary ravines deliver sediment to alluvial fans on the Green River valley floor. Lea Hill Creek is incising within its ravine. Soos Creek has formed a large alluvial fan at the upstream end of this reach. Most of the coarse sediment from Soos Creek settles out in low gradient reaches prior to reaching the Green.

Lower Green West

Drainage Area: 2,685 acres (4.2 square miles).

Tributaries: Includes the Green mainstem, Mullen Slough, and minor tributaries downstream of Mill Creek, to the confluence with the Duwamish.

Hydrogeology: This reach of the Green flows through extensive alluvium on the valley floor. Recessional outwash terraces line the western edge of the valley, and recharge valley floor aquifers.

Groundwater Recharge: Recessional outwash deposits cover 3.9 percent of the basin; 31 percent of these recharge areas are covered by impervious surfaces. 21 percent of the basin is covered by well-drained alluvial soils.

Soils: Alluvial soils on the valley floor cover 46 percent of the basin. Till soils cover 11 percent (primarily in side-canyon tributaries), and outwash soils are nearly absent.

Streamflow/Runoff Production: Most of the basin would historically have been inundated by floods from the Green River. Fine-grained alluvial soils saturate quickly, but historically much of the local runoff would have been captured by the depressional wetlands that occupied the valley floor. 1998 Landsat data show 20 percent forest and 41 percent TIA.

In 1916 the Cedar/Black River was diverted away from the lower Green/Duwamish into Lake Washington. The Black River is now a remnant channel that flows into the Green near the downstream end of the study area. Howard Hanson Dam keeps peak flood flows below 12,000 cfs below Auburn (Kerwin and Nelson, 2000).

The King County FIS assumed a constant peak flow of 12,000 cfs for the 10- through 500-year events for all reaches below Auburn (FEMA, 1989).

With the elimination of overbank flooding from the Green, flooding on the valley floor is now strongly driven by high groundwater levels in topographic depressions (FEMA, 1989). During floods the Green River is perched above groundwater, preventing subsurface drainage to the river. Perched ponds may also form in depressions that are lined with fine-grained soils.

The headwaters of Mullen Slough arise from lakes, wetlands, and seeps on the Federal Way drift plain, in rolling hills that lie 300-400 feet above the valley floor (Kerwin and Nelson, 2000). Historically, Mullen Slough conveyed water from valley floor wetlands to the mainstem Green River, served as an important flood storage area, and provided refugia to anadromous salmonids from winter high flows (Kerwin and Nelson, 2000). Levees now disconnect the Green River from the Mullen Slough floodplain, although floodwaters still backwater from the Green into the lower reaches of Mullen Slough.

Urban development, agriculture, and forestry have substantially increased stormwater runoff from tributaries. This has increased peak winter flows, reduced recharge of shallow aquifers, and decreased dry season flows. The effects of increased runoff on the mainstem Green are secondary in comparison to flow regime changes caused by diversions, channel modifications, and operation of the Howard Hanson Dam.

Storage Features: Large depressional wetland complexes once covered much of the lower Green Valley floor, and were fed by frequent flood flows, alluvial groundwater, and stormwater runoff. Remnants of these still exist, but no longer receive overbank flow from the Green. They still store runoff from tributary areas on the valley floor, and are fed by alluvial groundwater when water levels in the Green are high.

Geomorphology: The following review of channel morphology was taken from the WRIA 9 Limiting Factors and Reconnaissance Report: The diversion of the White River in 1906 dramatically reduced the supply of sediment to the lower Green. The White River once supplied 75 percent of the sediment to downstream reaches of the Green, although much of this was deposited in an alluvial fan at the historic mouth of the White that extended to about RM 27. The lower Green has responded to these changes by forming a new floodplain channel within the historic channel, with a new floodplain elevation at least 7-feet lower than the pre-diversion floodplain. Valley floor deposits downstream of the fan are mostly mode up of silt, clay, and fine sand interbedded with peat. About 90 percent of the once extensive floodplain is no longer inundated on a regular basis (Green River WQA Scope Document).

Levees and stream bank revetments affect over 80 percent of the length of channel between RM 25 and RM 31. Levees are virtually continuous along both banks downstream of RM 25.

Mullen Slough has been extensively ditched, and receives sediment from exposed eroding banks in both the ravines and the valley floor. Even under historic conditions the low-gradient channel contained few spawning gravels (Kerwin and Nelson, 2000).

Middle Green

Drainage Area: 20,971 acres (32.8 square miles).

Tributaries: Includes the Middle Green mainstem and tributaries upstream of Soos Creek. The subbasin includes small side canyon tributaries such as Crisp (5 square miles), O'Grady (1.3 square miles), and Burns Creek.

Hydrogeology: The valley floor is covered by modern alluvium. Below Newaukum Creek the valley walls are lined by seepage zones in advance outwash and pre-Fraser deposits exposed by steep bluffs. However, Pacific Groundwater Group (1999) found relatively low seepage rates from these edges of the Covington and Enumclaw uplands (when compared to the western edge of the Covington upland). Extensive recessional outwash deposits are found along the valley margins upstream of Newaukum Creek.

Tributaries arise from Osceola mudflow and glacial till deposits on the Enumclaw Plateau and glacial till on the Covington upland. These tributaries generally cut steeply through ravines before emerging onto alluvial fans on the valley floor.

Groundwater Recharge: Recessional outwash deposits cover 28.4 percent of the basin; 20 percent of these recharge areas are covered by impervious surfaces.

Soils: Till soils cover 44 percent of the basin; alluvial soils cover 10 percent. Outwash soils cover 27 percent of the basin.

Streamflow/Runoff Production: Runoff from till soils in tributary catchments is produced primarily as shallow subsurface interflow. The valley floor was historically inundated by frequent floods from the Green River. Fine-grained alluvial soils saturate quickly, but historically much of the local runoff on the valley floor would have been captured by depressional wetlands. Landsat data from 1998 show 54 percent forest and 19 percent TIA.

Kerwin and Nelson, 2000: In 1913 the City of Tacoma completed a diversion dam at RM 61 and began diverting up to 113 cfs from the Green River (about 12 percent of the average annual flow at Palmer). Howard Hanson Dam was constructed in 1961 for flood control and storage. The dam limits flows at the Auburn USGS gage to less than 12,000 cfs (the pre-dam 2-year event). The 2-year flow is now about 9,100 cfs, and the duration of moderate flows (3,500 to 9,000 cfs) has doubled. Natural flow simulations indicate that without the Tacoma diversion and Howard Hanson dam peak flows would range up to 29,000 cfs, and 16 percent of the annual peaks would be greater than 11,000 cfs at Palmer. The King County FIS assumed a constant peak flow of 12,000 cfs for the 10- through 500-year events for all reaches below Auburn (FEMA, 1989).

The reservoir collects runoff from the upper 220 square miles of the Green River basin. The dam was designed to provide flood protection up to the 500-year event (equivalent to a peak inflow of 65,000 cfs). During floods dam releases are controlled to keep flows at Auburn below 10,000 cfs as inflows to the reservoir are rising, and below 12,000 cfs as inflows recede. As inflows to the reservoir decline, reservoir discharges are reduced gradually to limit rapid river level changes that might lead to bank sloughing and fish stranding downstream. The dam fills and stores water through the early summer, and provides dry-season flow augmentation during the late summer/early fall. Flow augmentation partially compensates for the Tacoma diversion, but the average 7-day low flow is still reduced by 18 percent at Palmer and seven percent at Auburn. Flows at Auburn have failed to meet Ecology’s minimum instream flow requirements in 21 of the last 30 years.

Agriculture and rural residential development are the primary land uses in the Middle Green subbasin. Land clearing has caused substantial increases in stormwater runoff from tributaries (including Newaukum Creek and those discussed below). This has increased peak winter flows, reduced recharge of shallow aquifers, and decreased dry season flows. The effects of increased local runoff on the mainstem Green are secondary in comparison to flow regime changes caused by diversions, channel modifications, and operation of the Howard Hanson Dam.

Tributaries typically arise either from wetlands and lakes on the top of the drift plains, or from ravines and springs on the Green River valley walls. Based on King County stream flow gage 40D, mean annual flow in Crisp Creek for water years 1995 through 2000 was approximately 8.8 cfs. The mean annual one-day minima stream flow is about 2.5 cfs. The hydrology of the creek is dominated by groundwater and baseflow is the main component of the annual hydrograph. See Figure D-1 to D-3 for more information.

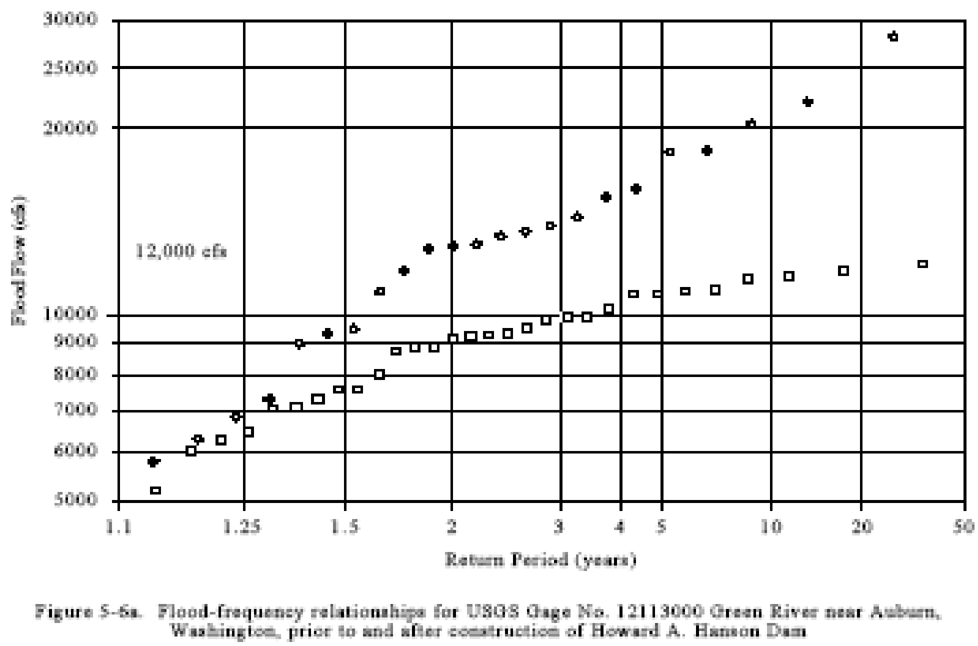


Figure D-1: Flood Frequency relationships on Green River Near Auburn.

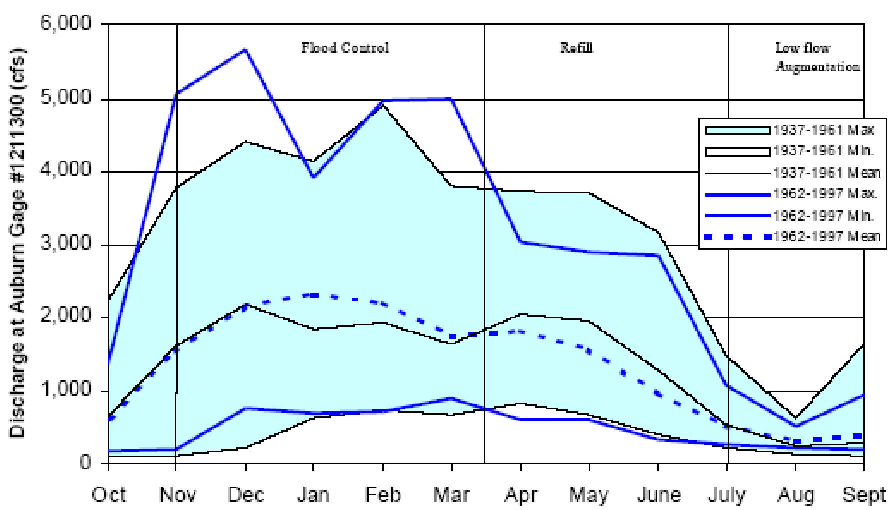


Figure D-2: Discharge of Green River Near Auburn.

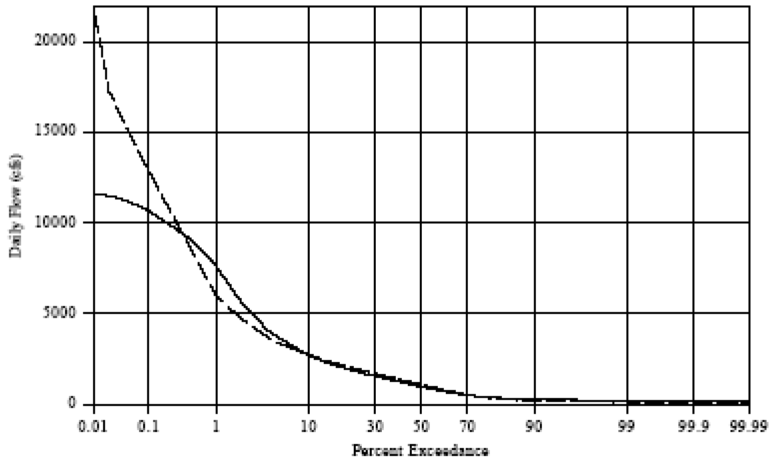


Figure 5-6b. Daily flow duration curves, USGS Gage 12113000, Green River near Auburn, Washington, prior to and after construction of Howard A. Hanson Dam.

Figure D-3: Daily Flow Duration Curves of Green River Near Auburn.

Areas underlain by mudflow deposits (such as the O'Grady basin) respond quickly to rainfall and generate high storm peaks. Increases in land conversion and impervious areas on the Enumclaw plateau have exacerbated this effect. Based on data for water years 1992-1995 for King County stream gage 40C, the mean annual flow rate for O'Grady Creek is approximately 1.5 cfs. The annual one-day minimum flow ranges from 0 - 0.4 cfs.

Storage Features: Areas underlain by mudflow deposits contain numerous clay-lined depressional wetlands, especially on the left bank and in the O'Grady creek basin. Oxbows and depressional wetlands store runoff on the valley floor.

Geomorphology: The following review of channel morphology was taken from the WRIA 9 Limiting Factors and Reconnaissance Report: Following glaciation, the Green River rapidly cut down through the unconsolidated glacial sediments to form a wide alluvial valley bordered by steep bluffs.

Between RM 57 and RM 45.6, the Green River flows through a steep gorge lined with bedrock and boulders. Below the gorge the Middle Green transitions from a transport reach to a depositional reach. Historically the channel meandered and braided freely across a wide floodplain. Flow and sediment regime changes, along with channel modifications, now limit channel migration and floodplain connectivity. Levees and stream bank revetments line one or both banks along approximately 40 percent of the mainstem Green River between RM 32 and RM 45.

The upper basin once supplied over 90 percent of the alluvial gravel deposited in the middle and lower reaches of the Green River. Howard Hanson Dam now traps nearly all of this coarse sediment, while allowing most of the suspended load to be carried downstream. This has resulted in a deficit of coarse sediment between RM 45 and RM 57, including the Green River gorge. The channel therefore incises until an armored layer of large sediment develops. This has already occurred between RM 61 and 57, and is beginning to affect reaches below the Green River Gorge.

Because of the loss of coarse sediment, local landslides now provide a large proportion of the total sediment supply to the Middle Green. These landslides generally contribute sands and fine sediment. Most of the streamside landslides occur where the channel flows adjacent to steep slopes on the valley walls. A slide at RM 43 delivered 50,000 cubic yards of sediment to the channel in 1996. Land disturbance and erosion in tributary channels have also increased the delivery of fine sediment to the Middle and Lower Green.

Both Newaukum and Soos Creek have formed alluvial fans where they enter the Green River Valley. The Newaukum Creek subbasin is an important source of sediment to the middle Green. Most of the coarse sediment in Soos Creek settles out in low gradient reaches prior to reaching the Green. Other smaller tributary creeks begin on top of the plateaus before steepening and flowing down to the valley floor through side-canyon ravines. They may deposit alluvial fans at the mouths of these ravines before flowing into the Green River through low-gradient channels (many of which are old river channels). The ravines are subject to slope failures and landslides, which send fine material downstream. In areas that drain mudflow deposits channels are often heavily scoured by high stormwater flows.

Mill Creek

Drainage Area: 9,673 acres (15.1 square miles).

Tributaries: Mill Creek enters the left bank of the Green River at RM 23.9, and is about 8.35 miles long.

Hydrogeology: The headwaters of Mill Creek begin on the eastern edge of the Federal Way upland drift plain. Tributary streams cut canyons through the till deposits on the upland bluffs, and intercept seepage zones in the bands of advance outwash and pre-Fraser deposits that are exposed at the base of the bluffs. These seepage zones also recharge alluvial aquifers and wetlands on the valley floor, and feed springs used for water supply by the City of Auburn. Mill Creek then turns northward and flows through extensive alluvial and wetland deposits on the Auburn-Kent valley floor.

Groundwater Recharge: Recessional outwash deposits cover 3.5 percent of the basin; 39 percent of these recharge areas are covered by impervious surfaces.

Soils: Fine-grained alluvium covers 38 percent of the basin; till soils cover 35 percent. Outwash soils cover only 0.7 percent of the basin.

Streamflow/Runoff Production: The headwaters of Mill Creek and Mullen Slough arise from four lakes (Dolloff, Fenwick, Geneva, and Star), wetlands, and seeps on the Federal Way drift plain, in rolling hills that lie 300-400 feet above the valley floor (Kerwin and Nelson, 2000). Most of the runoff from these till-covered headwater areas was historically produced as shallow subsurface interflow. The lower half of the basin lies on the Auburn-Kent valley floor, and is covered by low-gradient alluvial and wetland soils. These fine-grained soils saturate quickly, but runoff would historically have been captured in the extensive wetland complex that once dominated the lower basin. 1998 Landsat data show 16 percent forest and 46 percent TIA.

Historically, Mill Creek conveyed water from nearby wetlands to the mainstem Green River, served as an important flood storage area, and provided refugia to anadromous salmonids from winter high flows (Kerwin and Nelson, 2000). Flood waters from the

Green still backwater into the lower reaches of Mill Creek, but levees overbank flows from the Green from flowing into the Mill Creek floodplain. See Table D-3 for more information.

Table D-3: Flow Estimates from King County FIS.

Location	Drainage Area (square miles)	10-year Peak Flow (cfs)	100-year Peak Flow (cfs)
Green River confluence	12.8	250	410
Mill Creek at SR 167	8.0	180	310

Note: King County has a calibrated HSPF model of the subbasin.

Source: FEMA, 1989.

Storage Features: Runoff from headwater areas is attenuated by Dolloff, Fenwick, Geneva, and Star lakes. Wetlands once covered most of the lower valley floor, storing runoff and backwater flooding from the Green.

Geomorphology: Tributary creeks drop abruptly through steep canyons to the valley floor, where stream gradients flatten markedly. Mill Creek drops through Peasley Canyon before flowing onto the valley floor.

Erosion is a problem in the upper reaches and ravines. Lower reaches suffer from excessive sedimentation. Floodplain and wetland areas have been extensively filled along lower Mill Creek. Sediment also arises from borrow pit and construction sites, streambank erosion in Peasley Canyon, and runoff from urban and agricultural lands.

Mill Creek and its tributaries have been significantly altered, straightened, and ditched. State Route 167 constricts the ability of the creek to migrate. In the mid 1980s, the reach of Mill Creek from 29th Street N.W. to 37th Street N.W. was relocated parallel to SR 167 to allow construction of the Puget Power Christopher Substation as part of the Mill Creek Restoration (relocation) Plan. The new 100-year flood capacity channel meanders slightly and was revegetated with shrubs and trees. More recently, the stream reach from 37th Street NW to the north was relocated for a warehouse construction project.

Newaukum Creek

Drainage Area: 17,821 acres (27.8 square miles).

Tributaries: Newaukum Creek drains the Enumclaw uplands, flowing northwest from Enumclaw towards the Green River at RM 40.7 (near Black Diamond). The creek is about 14 miles long, plus 13.5 miles of tributary channels.

Hydrogeology: The Newaukum Creek basin drains portions of the Enumclaw upland drift plain. Most of the drift plain glacial deposits were covered 5,000 years ago by fine-grained deposits from the Osceola mudflow. Minor inclusions of till are scattered throughout the basin, and large areas of recessional outwash are found in the headwaters and along the Green River valley bluffs on the northern margins of the basin. The creek intercepts seepage from advance outwash and pre-Fraser deposits in the lower reaches, and transitions onto an alluvial fan on the Green River valley floor. Few alluvial deposits are found in the stream valleys.

Groundwater Recharge: Recessional outwash deposits cover 23 percent of the basin; 21 percent of these recharge areas are covered by impervious surfaces. HSPF modeling for the Green River WQA estimated basin-wide annual average groundwater recharge as 15.6 inches. Till and mudflow areas provide 12.4 inches of recharge, while outwash areas (concentrated in the headwaters) provide 30.0 inches.

Soils: Most of the subbasin is covered by till (34 percent) and volcanic mudflow (30 percent) soils, while 15 percent of the basin is covered by outwash soils. The basin has the highest percentage of wetland muck soils (4.5 percent) in the Green River portion of the study area.

Streamflow/Runoff Production: The headwaters of Newaukum Creek arise from diffuse springs, snowmelt, and groundwater runoff on Boise Ridge in the foothills of the Cascades. Mudflow deposits on the Enumclaw Plateau are relatively impervious, and produce runoff much more rapidly than do other drift-plain tributaries in the Green watershed. King County DNR (1997) found that streamflows from a January 1997 storm peaked more than 2 days before streamflows peaked in outwash-dominated basins like Soos Creek. Mudflow deposits have typically been modeled as "till" in HSPF studies. The Newaukum basin is the most agricultural subbasin in the Green River watershed, with 35 percent grass/shrub/crop land cover. Landsat data from 1998 show 36 percent forest and 21 percent TIA.

Water withdrawals (surface and ground water), the conversion of historic forest lands to agricultural lands, and the elimination of historic wetlands have reduced low flows on the Enumclaw Plateau (Kerwin and Nelson, 2000). The average 7-day low flow in Newaukum Creek decreased significantly between 1968 and 1993.

Newaukum Creek was not studied in detail in the King County FIS (FEMA, 1989). Table D-4 lists the following streamflow statistics from the WSDOT Hydraulics Manual (1997).

Table D-4. Streamflow statistics for Newaukum Creek.

Location	Drainage Area (square miles)	10-year Peak Flow (cfs)	100-year Peak Flow (cfs)
USGS Gage near Black Diamond	27.4	1230	2180

Konrad and Booth (2002) compared flow statistics for urban and rural streams, and identified the following flow statistics for the Newaukum Creek USGS gage:

- Mean annual maximum discharge: 667 cfs (CV = 0.45)
- Mean 7-day low flow: 15 cfs (CV = 0.22)
- Mean Fraction of year annual mean discharge was exceeded: 0.35 (CV = 0.10)
- Mean annual mean discharge: 60 cfs (CV = 0.24).

This basin was classified as rural, with relatively slow population growth from 1970 through 2000. Only the 7-day low flow showed a significant trend over the 10-year period analyzed (negative correlation with population growth).

A detailed HSPF model was developed and calibrated as part of the Green River WQA study (King County and Aqua Terra Consultants, 2003). The model was calibrated against flow data collected at the USGS gage. King County operates one rain gage within the basin (East Enumclaw gage 44U), and has about 2 years of flow data at three stream gages (Clovercrest Outfall 44F, Newaukum tributary 44G, and North Fork Newaukum 44H). Mean annual precipitation in the basin is about 49 inches. The model used 29 catchments with areas ranging from 36 to 1460 acres.

Table D-5 lists the following overall water balance results for October 1998 – September 2002, produced by the model.

Table D-5. Overall water balance results, Oct. 1998 to Sep. 2002.

Component	Till and mud-flow soils	Outwash	EIA	Watershed Average
Precipitation	50.5	53.5	52.4	51.6
Surface Runoff	0.8	0.03	43.7	3.1
Interflow	14.9	0.11	0	10.9
Baseflow	11.1	27.1	0	14.2
Evapotranspiration	23.0	23.1	9.7	22.3
Deep GW Recharge	0.6	1.5	0.0	0.7

Note: all units are inches.

The model was also calibrated to simulate daily water quality, including temperature, DO, sediments, and various pollutants; plots are presented in the report.

Storage Features: The basin has no major lakes. The relatively flat mudflow deposits contain numerous clay-bottomed depressions that historically developed into wetlands. Many of these have been ditched and drained for agriculture.

Geomorphology: The mainstem Newaukum Creek and the North Fork Newaukum Creek drop down steep ravines and gullies to meet on the Enumclaw Plateau. The creek crosses the plateau and flows down a steep-walled ravine for the last three river miles before entering the Green River.

The upper channel (RM 14 to RM 9) is a high-gradient confined channel (Kerwin and Nelson, 2000). On the Enumclaw Plateau (RM 9 to RM 3) the channel flows through an unconfined floodplain, with an average gradient of 0.5 percent. The lower 3 miles flow through a steep ravine with a gradient of 2.7 percent. The channel within the ravine is moderately to tightly confined, but has been heavily altered by landowners near the mouth. The ravine extends to the confluence with the Green River, with only a short segment of alluvial fan (about 1,500 feet) extending into the Green River valley.

Historic forest practices and development on Alderwood and Kitsap soils in the lower ravine have exacerbated erosion and slope instability. Scour within the channel has removed much of the suitable substrate in this reach, and forms a gravel fan at the mouth. This fan has been periodically excavated to allow upstream Chinook migration. Boehm (1999) found a mixture of large gravel (35 percent), cobble (30 percent), small gravel (20 percent) and sand (15 percent) in the lower mile of the creek (Kerwin and Nelson, 2000).

Soos Creek (Including Jenkins and Covington Subbasins)

Drainage Area: 44,875 acres (70.1 square miles).

Tributaries: Soos Creek drains the Covington drift plain, and flows south from the northern study area boundary and into the Green River near Auburn. Major tributaries include Little Soos Creek (Soosette Creek), Jenkins Creek (10,189 acres), and Covington Creek (14,280 acres).

Hydrogeology: Soos Creek drains till and recessional outwash deposits on the Covington drift plain. Soos, Jenkins, and Covington Creeks occupy broad recessional outwash valleys. Soos Creek intercepts groundwater in advance outwash and Pre-Fraser deposits below Jenkins Creek. Alluvium is found only in the lower 2 miles where Soos Creek transitions out of a canyon onto an alluvial fan on the Green River valley floor.

Groundwater Recharge: Recessional outwash deposits cover 36.5 percent of the basin; 34 percent of these recharge areas are covered by impervious surfaces. Outwash deposits are most prevalent in the Jenkins and Covington subbasins. Woodward et al. (1995) developed a basin-wide water budget for Soos Creek. Total recharge was 20.6 inches per year; 17.0 inches of this is returned to streams as baseflow. The remaining 3.6 inches flows downward from shallow groundwater storage in till and recessional outwash to the deeper advance outwash and pre-Fraser aquifers. Groundwater pumping removes as much as 2 inches per year, although much of this is returned through septic systems.

Soils: Glacial outwash soils cover 35 percent of the basin, and till soils cover 51 percent. Jenkins and Covington contain 56 and 43 percent outwash soils, respectively. Few alluvial soils are mapped in the subbasin. The Covington subbasin contains the highest percentage of colluvial soils in the study area (11.4 percent).

Streamflow/Runoff Production: The basin is dominated by glacial deposits, with runoff produced primarily as interflow and groundwater-fed baseflow. Runoff response closely follows the model described by Dinicola (2002) for outwash-dominated basins. Numerous lakes and valley bottom wetlands delay runoff and provide flood storage. King County DNR (1997) estimated that flows peaked three days after precipitation had peaked during a January 1997 storm. 1998 Landsat data show 39 percent forest and 29 percent TIA. Table D-6 gives flow estimates from King County FIS for Soos Creek.

Table D-6: Flow Estimates from King County FIS for Soos Creek:

Location	Drainage Area (square miles)	10-year Peak Flow (cfs)	100-year Peak Flow (cfs)
USGS Gage	66.7	1130	1550
Below Covington Creek	49.4	870	1190
Above Covington Creek	31.2	580	800
Above Jenkins Creek	13.5	270	390
Above Little Soos Creek	9.3	200	280

Source: FEMA, 1989

King County (1997) estimated that the February 1996 flood increased the 100-year peak flow to between 2500 and 3200 cfs at the USGS gage (double the FIS estimate).

Konrad and Booth (2002) compared flow statistics for urban and rural streams, and identified the following flow statistics for the Soos Creek USGS gage:

- Mean annual maximum discharge: 720 cfs (CV = 0.42)
- Mean 7-day low flow: 25 cfs (CV = 0.20)
- Mean Fraction of year annual mean discharge was exceeded: 0.39 (CV = 0.10)
- Mean annual mean discharge: 123 cfs (CV = 0.27).

Despite population growth in this suburban watershed, only the 7-day low flow showed a significant trend over the 10-year period analyzed (negative correlation with population growth).

The Soos Creek subbasin is changing from forested/rural to urbanized (particularly in the western areas). The subbasin has an extensive system of interacting lakes, wetlands and infiltrating soils that collectively attenuate peak stream flows (Kerwin and Nelson, 2000). The Soos Creek Basin Plan (King County, 1990) provides detailed subcatchment peak flow tables and maps for various future and existing conditions HSPF modeling. The basin plan predicted that peak flows would increase by an average factor of 1.8 under build-out conditions. However, flows in some areas were predicted to increase by as much as 3.5 times, due to urbanization on soils with high infiltration rates.

Groundwater withdrawals and new impervious surfaces in the Covington Upland have reduced baseflows in Soos Creek. The mean annual flow decreased about 14 percent and the low mean monthly flow decreased about 33 percent between 1967 and 1992 (Culhane 1995). The average 7-day low flow in Soos Creek decreased significantly between 1968 and 1993.

King County has a calibrated HSPF model of the Soos Creek basin (Green WQA Study). Soos Creek, including Jenkins and Covington, was one of the watersheds used by Dinicola (1991 and 2002) to develop generalized HSPF parameters for Puget Lowland glaciated catchments.

The water balance recharge model developed by Woodward et al. (1995) found that out of an average annual precipitation volume of 47.8 inches, 9.0 inches was converted to runoff (interflow plus surface), 17.0 inches went to streams as baseflow, and 19.3 inches was lost to evapotranspiration. See Figure D-4 for more information.

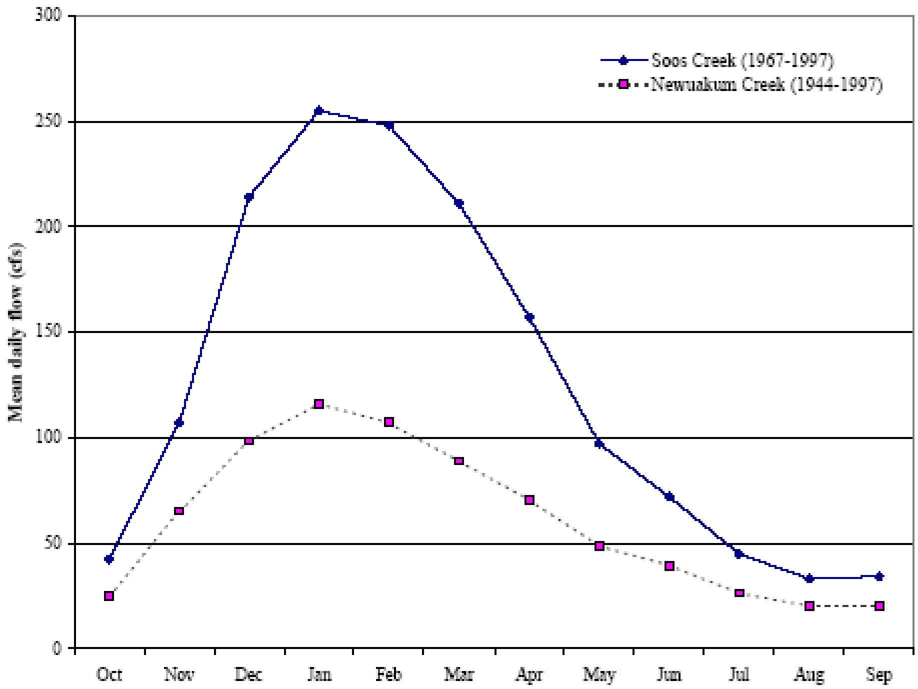


Figure D-4. Mean Daily Flow, Soos Creek and Newaukum Creek.

Storage Features: The Soos Creek basin contains a number of large lakes, including Lake Youngs (a domestic water supply for the City of Seattle), Shadow Lake, Lake Meridian, Lake Sawyer, Morton, Pipe/Lucerne and Wilderness Lakes. These lakes have a combined surface acreage of 1,370 surface acres (Wolcott 1973). The basin contains numerous wetlands in glacial kettle depressions and recessional outwash stream bottoms.

Geomorphology: Soos Creek begins on a rolling glacial outwash plain, where the channel is unconfined and flows at a gradient of less than 0.1 percent though a series of wetlands (Kerwin and Nelson, 2000). Flows in this reach have little erosive energy, and the channel substrate consists of alternating sections of gravel and swampy, mud-bottomed reaches.

At RM 4.75, Soos Creek enters a narrow, steep-sided ravine containing long riffles with pools. The channel gradient steepens to about 1.4 percent. Downstream of RM 2 the channel gradient decreases to 0.5 percent, and Soos Creek develops an unconfined floodplain within the steep-sided valley. The creek discharges onto an alluvial fan before entering the Green River.

King County (1990) identified sedimentation as a problem between RM 7.2 to 10.4. Sedimentation is also a problem in the lower reaches of Soos Creek, near the Green River fish hatchery (RM 0.8). Bank failures and bank erosion are common in Soos

Creek between Jenkins and Covington Creeks, at RM 4.6, and in the lower 0.6 miles of Covington Creek. In January 1990 a dam break flood from a blocked road culvert in Soosette Creek delivered nearly 30,000 cubic yards of sediment to Soos Creek.

Fennel Creek Subbasin

To be added later.

Lake Tapps Subbasin

To be added later.

Lower Carbon River Subbasin

To be added later.

Lower White East Subbasin

To be added later.

Lower White West Subbasin

To be added later.

Mid Puyallup North Subbasin

To be added later.

Mid Puyallup South Subbasin

To be added later.

Potholes Subbasin

To be added later.

South Prairie Creek Subbasin

To be added later.

Characterization of Wetland Resources within the SR-167 Study Area

The purpose of this narrative is to characterize wetland resources within the SR-167 study area. We do this by organizing and presenting wetland data compiled through photo interpretation and stored as a potential wetland restoration site dataset in ArcMap. Wetland data are stratified into three distinct landscape scales and summarized in narratives and as tabular data to: a) describe wetland resources, b) gain understanding into the general landscape position of wetlands, and c) summarize the effects of human alteration.

Methods

Photo interpretation

Photo interpretation of the 350 square mile study area was completed using 2002 nine inch square, 1:12,000 high resolution color stereo pairs and a two power stereoscope. A potential wetland restoration database was developing as a data file in ArcMap. Hydric soils data and all wetland inventories available for the study area were used as a tool to assist in the identification of current and potential wetland areas. Methods follow Gersib et al. (2004). Approximately one week of field verification was done at the start of photo interpretation to help calibrate signatures on photos with vegetative signatures on the ground.

Special attention was placed on identifying and evaluating wetlands within the project area. Wetland sites initially identified from existing wetland data compiled when completing previous projects along the SR-167 corridor. From this initial information, a wetland biologist visited each site and compiles information on location, extent, and condition of each wetland. Methods used in the identification and assessment of wetlands within the project area follow methods in Gersib et al. (2004). All site-specific data were entered into the existing potential wetland restoration database in ArcMap.

Special attention was also placed on incorporating and integrating the Mill Creek Special Area Management Plan (SAMP) (U.S. Army Corps of Engineers 2000) data into our potential wetland restoration data format. Polygons identified in the SAMP were used and described through photo interpretation in the same manner as all other potential wetland restoration sites.

Following the completion of photo interpretation at the study area scale and wetland assessment within the project area, wetland data from the completed potential wetland restoration site dataset were then extracted and placed in an Excel spreadsheet for analysis and summary.

Development of Spatial Scales

Variability of natural landscapes in time and space influence wetland form, function, and extent. Stratification of the natural landscape is a valuable tool in understanding wetland resources and how they respond to different human activities.

Wetland data are presented in three spatial scales. The study area was subdivided into Drainage Analysis Units (200-2,000 acres) and Subbasins (major stream catchments).

Definitions and methods for establishing these spatial scales follow Gersib et al. (2004).

A third spatial scale, called lithotopo units, was developed and used to characterize wetland resources. Unlike the Drainage Analysis Unit and Subbasin scales that are based on surface water flow paths, lithotopo units are based on topography and geology. Rationale and methods for establishing lithotopo units for the study area follow.

At the broadest scale, climate, geology, and topography dictate general runoff characteristics, substrate type, and slope (Montgomery 1999). Geomorphic provinces (Montgomery 1997) or Level III ecoregions (Omernik 1995) have large-scale geologic and climatic processes that control the distribution of relief, slopes, stream profiles, and ecological processes that influence natural resource characteristics and dynamics. The SR-167 study area occurs in the Puget Lowland ecoregion (Omernik 1995). Ecoregions can be further subdivided into landform assemblages termed lithotopo units (Montgomery 1997) of similar topography and geology. This unit, roughly equivalent to a Level IV ecoregion, further stratifies landscapes into areas suitable for the general characterization of wetland resources at landscape scales due to their similar geologic origin, landscape position, and hydrology. We make this assumption based on unpublished work by the author in the Nooksack River Basin in Northwest Washington State and an understanding of the location and extent of wetland resources within the SR-167 study area.

A shaded relief map of the study area was developed from 10 meter Digital Elevation Model data and used to gain understanding of topographic differences in the study area. Available digital geology data (Washington State Department of Natural Resources) local geology reports (Walters and Kimmel 1968, Luzier 1969, Woodward et al. 1995) were then used to gain understanding of important geologic features that influence the location and extent of wetland resources in the study area. Using these topography and geology resources, lithotopo units were developed for the study area.

Results

Data Limitations

The potential wetland restoration site dataset was developed as an initial tool in the identification and prioritization of potential wetland restoration sites. Limited field validation of photo-interpreted sites was done outside of the project area. All candidate sites will require detailed field evaluation before true site viability can be determined.

Photo interpreting the location and extent of forested wetlands is challenging, at best. Error rates in identifying forested wetlands in Western Washington have been estimated as high as 50 percent for existing National Wetland Inventory data. While a substantial portion of the study area has been cleared and hydric soils data and all available wetland inventories were used to help direct the photo-interpreter to like wetland sites, it must be acknowledged that our estimates of unaltered forested wetlands will be lower than what actually exists on the ground. This error will not affect the use of this dataset for identifying potential mitigation sites, but it will affect our characterization of the condition of existing wetland resources.

All wetland sites within the project area were field verified by a wetland biologist. Site visits within the project area were used to verify the presence and general extent of each site. Wetland polygons within the project area are estimates. Wetlands were not delineated and wetland polygons do not represent a jurisdictional boundary.

The potential wetland restoration site dataset developed here is not an inventory of existing wetlands. While existing wetlands are included in the dataset, out purpose was to characterize the condition of existing and historic wetlands. This means that wetland polygons represent the photo-interpreters estimation of a wetlands potential area, not its existing location and extent. Some wetland polygons in the potential wetland restoration dataset currently represent filled or highly degraded wetlands that have restoration potential but are not jurisdictional wetlands. Another site may have been a 100 acre wetland under pre-development conditions but, due to surface drains and subsurface tile, has been reduced to only 10 acres in size. In this example, the photo-interpreters goal was to identify the 100 acre potential wetland rather than the 10 existing wetland acres.

Potential Wetland Restoration Site Data

All potential wetland restoration site data compiled for the SR-167 study area are stored in an ArcMap data file available on request in CD format. Metadata are included with the data file and define/describe all key terms and attribute fields. Detailed information and methods are available in the most current watershed characterization methods document at:
http://www.wsdot.wa.gov/environment/watershed/technical_report.htm.

Key terms requiring definition and explanation:

Current and Potential Wetlands – natural wetlands that currently exist or have potential to exist in the future, if restored. We assume that all current and potential wetland sites were natural wetlands in the present or past. Wetland polygons, coded Potwet = Y, in the potential wetland restoration site dataset include sites that are jurisdictional wetlands under current conditions as well as sites that were wetland prior to human alteration. These sites may or may not be considered to be jurisdictional wetlands under current conditions.

Pre-development wetlands – wetlands existing at the time of early European settlement. The area of pre-development wetlands was estimated using GIS, existing hydric soils data and the potential wetland restoration site dataset. A comparison of hydric soils and existing and potential wetlands revealed that many of the existing natural wetlands were not identified as having hydric soils in the soils data. Wetland area at the time of early European settlement was calculated by adding the acres of hydric soils to the acres of current and potential wetlands not on a listed hydric soil and deleting deepwater lake areas.

Wetland Data Summarized by Lithotopo Unit

Wetland resources in the SR-167 study area were subdivided into four lithotopo units, based on surficial geology (see Figure 44 in main body of this document) and topography. A master wetland data table was developed that groups and summarizes data by lithotopo unit. A landscape characterization of wetland resources by lithotopo unit follows. While the potential wetland restoration site database has information on both wetlands and deepwater lakes, the following narrative summarizes wetland resources and excludes deepwater lakes, unless specifically noted.

Condition of Wetland Resources by Lithotopo Unit

The study area is subdivided into four lithotopo units. Two units, the Covington Drift Plain and the Southwest Till Plains, are predominantly glacial till deposits while the Osceola Mudflow Plain represents an area of lahar deposits from Mount Rainier and the Alluvium Deposits represent the major unconfined floodplain areas of river systems (Woodward et al 1995).

The comparison of wetland resources within each lithotopo unit reveals striking differences in wetland extent, type, and condition. The predevelopment extent of wetlands on the two glacial till-based lithotopo units was numerically similar, estimated to have represented 9 percent of each unit. In contrast, predevelopment wetlands on Alluvium Deposits and the Osceola Mudflow Plain are estimated to constitute 44 percent and 56 percent of their respective lithotopo units. When the extent of current and potential wetlands is compared to predevelopment wetland extent, results provide insight into differing levels of wetland vulnerability to human land uses. Topographically, the Alluvium Deposits and Osceola Mudflow Plain lithotopo units represent relatively flat landforms that were cleared early in European settlement for agricultural purposes. This landform also facilitated wetland drainage that, in part, resulted in an estimated 60 percent reduction in wetland area for both lithotopo units. Conversely, the glacial till lithotopo units have a rolling hill landform with wetlands commonly occurring in deeper topographical depressions or on areas of substantial groundwater discharge on recessional outwash. We suggest that these wetlands on the Covington Drift Plain and the Southwest Till Plains have reduced potential for wetland drainage and development compared to the flatter landforms of the Osceola Mudflow Plain and Alluvium Deposits lithotopo units. These assumptions are supported by wetland loss estimates that indicate that the two lithotopo units with a rolling hill landform (Covington Drift Plain and Southwest Till Plains) have retained greater than two-thirds of all pre-development wetlands under current conditions, compared to only 40 percent for the flatter Alluvium Deposits and Osceola Mudflow Plain lithotopo units.

A comparison of the proportion of current or potential wetlands in an unaltered condition also reveals important differences by lithotopo unit. Results indicate that the two units associated with glacial till, Covington Drift Plain and Southwest Till Plains, have 46 percent and 49 percent of current or potential wetland acres with little or no evidence of hydrologic or vegetative alteration. Similarly, Alluvial Deposits have 43 percent of remaining wetlands in an intact condition. In contrast, results indicate that the Osceola Mudflow Plain has only 6 percent of current and potential wetland acres with little or no evidence of hydrologic or vegetative alteration.

When past wetland losses and current/potential wetland conditions are compared, results indicate that wetlands on the Osceola Mudflow Plain has experienced both the greatest wetland loss (59 percent) and the highest level of current and potential wetland alteration (94 percent).

One final comparison relates to differences in the type of wetlands that occur within each lithotopo unit. Photo interpretation, using stereo-paired photos, was used to establish a current and potential hydrogeomorphic wetland class (Brinson 1995) for each wetland polygon. Depressional wetlands represent the dominant wetland class on the Southwest Till Plains (71 percent of wetland acres), Covington Drift Plain (83 percent of wetland acres), and Osceola Mudflow Plain (94 percent of wetland acres). In each of these three units, riverine wetlands represented a majority of all remaining wetland classes. As expected, the one exception to this is the Alluvium Deposits in which riverine wetlands comprise 59 percent of the wetland acres with the remaining 41 percent being depressional wetlands.

Covington Drift Plain

The Covington Drift Plain makes-up the northeast portion of the study area and encompasses all of the Soos Creek, Jenkins Creek and Covington Creek Subbasins and till plain portions of the Black River, Lower Green East, Middle Green River, and Upper Newaukum Subbasins.

Geologic Origin

Quaternary geologic history indicates that the Vashon Stade ice sheet reshaped this lithotopo unit between 13,500 and 15,000 years ago (Luzier 1969, Woodward et al. 1995). Nearly all of this area is underlain with glacial till, deposited and compacted by the advancing Vashon ice sheet. A large portion of the northwest one-third of the area is exposed glacial till, along with numerous large till outcrops distributed throughout the remainder of the area. As the ice sheet melted, large quantities of water and sediment were produced. Large streams in temporary positions adjacent to the receding ice margin formed melt water channels that deposited extensive recessional outwash deposits over the glacial till in a large part of the southern and eastern two-thirds of this lithotopo unit. Since the Vashon Stade, peat has formed in numerous depressions on both glacial till and recessional outwash deposits.

Wetland Resource Characterization

The extensive matrix of glacial till and recessional outwash within this lithotopo unit facilitate a diverse complex of wetlands and deepwater lakes that result in equally diverse wetland form and function. Depressional wetlands dominate within this lithotopo unit and peat wetland systems are numerous. Peat bogs and rich fens represent a unique type of wetlands that are dependent on specific topography and hydrologic inputs that humans have yet to replace in-kind. Peat wetlands on glacial till tend to be bogs, characterized by headwater wetlands or wetlands in the upper parts of stream catchments. Under these conditions, precipitation on or near these wetlands tends to dominate hydrologic inputs, resulting in naturally nutrient poor systems that develop Sphagnum peat. Soils data also indicates the presence of depressional wetlands on mineral soils within glacial till. We anticipate that these wetlands have hydrologic inputs dominated by surface water runoff from greater distances, resulting in improved nutrient inputs and greater variability in flow regime. Also prevalent in this area are peat systems associated with recessional outwash deposits and stable groundwater discharge. We expect wetland systems developing under these conditions to be forested swamps and nutrient rich fens. Depressional wetlands on recessional outwash deposits and mineral soils likely reflect sites having hydrologic inputs dominated by surface water flow rather than by groundwater. In the vicinity of Lake Youngs and Lake Taps, glacial fluting and lineation of the glacial till surface has resulted in numerous long linear wetlands oriented in a northwest to southeasterly direction.

The Covington Drift Plain lithotopo unit has an extensive area of unconfined aquifers associated with recessional outwash deposits and the numerous headwater lakes and wetlands on till deposits. We would expect these wetlands and the extensive area of unconfined aquifers to provide strong stable baseflows for major streams in this lithotopo unit, under pre-development conditions. In comparison, we would expect stream flows in the Osceola Mudflow Plain and the Southwest Till Plains lithotopo units to support proportionally lower stream baseflows and experience more “flashy” runoff events. Further, wetlands on recessional outwash that function to recharge the unconfined aquifer function as a contributing source of cool water that helps maintain cool stream temperatures under summer baseflow conditions.

Riverine wetlands within the Covington Drift Plain can be subdivided into two groups, based on their occurrence on glacial till or recessional outwash deposits. Riverine wetlands on till tend to be more precipitation/runoff driven and tend to have limited potential to receive substantial groundwater inputs. Wetlands on till will receive seasonal sub-surface flows but will likely only receive groundwater throughout the growing season if the stream system cuts through the till layer and into advanced outwash deposits. Conversely, riverine wetlands on recessional outwash will likely interact with unconfined aquifers associated with this geologic setting. Depending on specific site conditions, these wetlands have increased potential for groundwater recharge and/or discharge.

Osceola Mudflow Plain

The Osceola Mudflow Plain makes-up the east central portion of the study area and encompasses portions of the Middle Green River, Newaukum, Lower White East, Lake Tapps, Fennel Creek, and South Prairie Creek Subbasins.

Geologic Origin

Quaternary geologic history indicates that the Vashon Stade ice sheet was the most recent advance and retreat of ice, reshaping this lithotopo unit between 13,500 and 15,000 years ago (Luzier 1969, Woodward et al. 1995). Nearly all of this area is underlain with glacial till, deposited and compacted by this advancing ice sheet. Where it not for a major mudflow from Mount Rainier approximately 5,000 years ago, this area would likely have similar geology and topography as that of the Covington Drift Plain to the north and east. This large volcanic event, called the Osceola Mudflow, flowed down the White River valley to the edge of the Puget Sound Lowland southeast of Enumclaw, Washington. At this point, the mudflow spread out over at least 65 square miles of Puget Lowland. A portion of the mudflow moved south and west, reaching the floor of the Puyallup Valley, by way of the glacial outwash channels now being occupied by Fennel and South Prairie Creeks. The mudflow filled the pre-mudflow White River valley, most likely the valley now occupied by South Prairie Creek (Crandell 1963), and diverted it to its present northwesterly alignment. A larger portion of the mudflow moved in a northwesterly direction before flowing over the south wall of the Green River valley (Luzier 1969). This lithotopo unit consists primarily of Osceola Mudflow deposits with scattered areas of glacial till, primarily in the north central part of the unit, that extend above the mudflow deposits.

Wetland Resource Characterization

The Osceola Mudflow filled existing natural surface drainage features and created a large relatively flat lahar fan consisting of very fine to course material that restricts downward water movement. As these lahar deposits stabilized, the nearly flat landform resulted in poorly developed natural surface drainage networks. Low soil permeability, flat topography, and a poorly developed surface drainage network facilitated the formation of extensive areas of wetlands and shallow lakes.

Hydric soils data indicate that pre-development wetlands within the Osceola Mudflow Plain were much larger in size than depressional wetlands in the other lithotopo units. To provide some perspective of size, two hydric soils polygons on the Osceola Mudflow Plain each extend across all or parts of 20 to 30 square miles. Using soils data and the vegetative composition of remnant wetlands that remain, it is likely that extensive areas of forested wetland were common on the Osceola Mudflow Plain. Based on the presence of smaller peat soil types within these larger hydric soils polygons, it is likely that smaller emergent and scrub shrub wetland polygons occurred within the more extensive forested wetland areas. These wetter areas are commonly represented by Seattle muck, Shalcar muck, and Tukwila muck soil mapping units in county soil surveys (Snyder et al. 1973, Zulauf 1979).

Wetlands on the Osceola Mudflow Plain receive water from precipitation and surface water flow. The lack of topographic relief and tight soils restrict groundwater input to wetlands. The shallow expansive nature of Osceola Mudflow wetlands and their predominantly mineral soils imply that large portions of these wetlands had a seasonal water regime that experienced an annual dry period each year. Smaller areas where peat developed likely held water for all or most of an average year.

Since the deposition of the Osceola Mudflow some 5000 years ago, there is evidence that natural erosional processes cut into the valley walls of the Green and White Rivers and, in some cases, extended beyond the valley wall and into areas of hydric soils on the Mudflow Plain. However, even these naturally drained wetlands were likely maintained by beaver dams near the wetland outlet were low gradient and a lack of stream power facilitated their construction and maintenance.

Early European settlers sought out flat ground to develop, and the Osceola Mudflow Plain was no exception. We estimate that 56 percent of this lithotopo unit was in wetlands at the time of European settlement. Based on existing wetland inventories and aerial photo interpretation, we estimate that approximately 40 percent of these wetlands remain today or have some potential for restoration. Using these numbers, we estimate that some 14,000 wetland acres have been converted to upland land uses. Results of aerial photo interpretation also indicate that over 90 percent of all current and potential wetlands within the Osceola Mudflow Plain have some level of hydrologic and vegetative alteration.

Due to the extensive loss and degradation of wetlands in the lithotopo unit, the restoration of wetlands would appear to have added ecological significance. However there is growing evidence that wetland restoration potential is declining, in some parts of this area. Photo interpretation provides insight into new land use changes that affect wetland restoration potential. Much of this lithotopo unit was originally cleared and drained for agricultural uses. Some large dairies remain, but change is evident as new multi-home developments and large single family homes on acreages are encroaching into these agricultural areas. Wetland restoration potential is affected by the location of these homes and developments. Farms and dairies were observed consistently on knots of glacial till or other "high ground", rather than the lower wetland soils. However, there were numerous times when homes on acreages were built on drained hydric soils and some instances where homes were built in areas that appeared to have existing wetland signatures all around the home. Numerous potential wetland restoration polygons were excluded from further consideration because of this type of development. This narrative description is not intended to be critical of this land use change. Rather, this change is highlighted to identify a growing threat to the restoration of these natural resources.

Alluvial Deposits

The Alluvial Deposits lithotopo unit encompasses major floodplain/alluvial deposits within the Green, White, Carbon, and Puyallup Rivers along with smaller floodplain areas associated with South Prairie Creek and lower Soos Creek.

Geologic Origin

Quaternary geologic history indicates that the Vashon Stade ice sheet reshaped this lithotopo unit between 13,500 and 15,000 years ago (Luzier 1969, Woodward et al. 1995). Evidence indicates that the alluvial deposits in the north-to-south Kent/Auburn Valley area were once an embayment to Puget Sound. During much of the Vashon glaciation, this embayment received meltwater that formed a delta of recessional sand below Auburn. This was later covered and filled by sequences of Holocene alluvium and mudflow deposits (Pacific Groundwater Group 1999). After the Vashon glaciation, the Green, White, and Puyallup Rivers began cutting valleys across the drift plain, depositing alluvium underlain by mudflow and pre-Fraser glacial deposits. Approximately 5000 years ago an extensive Holocene mudflow from Mount Rainier, called the Osceola Mudflow, moved down the White River. When mudflows reached the glaciated Puget Lowland they formed a large fan that created the Osceola Mudflow Plain and diverted the White River, from it's southerly route, most likely the South Prairie Creek valley, to its present northern position (Crandell 1963). Lahar deposits from this mudflow, natural sediment deposition from each river basin, and the reworking of this material by natural river processes formed the Green and White River floodplains that currently exist. The Puyallup River received lahar deposits from the Osceola Mudflow via remnant glacial outwash channels now occupied by Fennel and South Prairie Creeks. However, deposition from this White River lahar were buried by the Electron Mudflow from Mount Rainier that flowed down the Puyallup River some 500 years ago. Current geology maps still delineate substantial lahar deposits from this mudflow within the Puyallup River floodplain from Orting north to the White River (Figure XX [tsj:\wc6.mxd]).

Wetland Resource Characterization

Hydric soils blanket large areas of the Alluvial Deposits lithotopo unit. We estimate that approximately 44 percent of this lithotopo unit (23,000 acres) was wetlands prior to European settlement. Like most other Puget Sound rivers, the large floodplains of the Green, White, and Puyallup Rivers where once a complex network of wetlands, side channels, oxbows, beaver ponds, and active channel systems. Large wood was abundant in these systems. Snags and logjams created and maintained a diverse channel system, while a mixed deciduous and coniferous forest shrouded much of the floodplain area.

Wetlands were diverse and abundant in these lower floodplain systems. High winter water tables in many areas created large expanses forested floodplain wetlands. Oxbows, abandoned side channels, and an extensive network of beaver ponds created a mosaic of wetlands with year-round water interspersed among larger temporarily- and seasonally-flooded forested wetlands. In a similar manner, hydrologic inputs to these wetlands were likely as complex as the wetlands they fed. Peat soils along the valley walls of the lower Green, White, and Puyallup Rivers indicate wetland areas receiving very stable water supplies, most likely from groundwater discharge. Oxbows and some of the deeper side channels likely received shallow hyporheic flows nearly year-round, while other shallower wetland depressions within the floodplain received hyporheic flows seasonally as the water table approached ground level. Surface water flows from over-bank flooding and from streams flowing off adjacent till plains also served as a water source for many wetlands within this lithotopo unit. Finally, the presence of beaver and their ability to dam side channels and floodplain streams created additional wetland diversity and area by impounding water on the surface of the floodplain. Depending on landscape position within the floodplain, wetlands in a pre-development condition often had multiple water sources that changed seasonally. Under these hydrologic conditions, riverine wetlands were the dominant hydrogeomorphic wetland class on alluvial deposits.

Wetlands within the lower Green (Auburn north), White (Auburn south), and Puyallup (Orting north and west) floodplains have experienced extensive hydrologic and vegetative alteration that started in the early 1870s and intensified as motorized heavy equipment came available. Developed first for agricultural uses, drainage ditches, channelized streams, and diked rivers individually and cumulatively reduced and simplified water sources to a diminishing wetland resource. Later, extensive pre-development wetland areas in the lower Green and White Rivers were filled and developed for residential, commercial, and industrial uses. Development in the study area portions of the lower Puyallup floodplain appears to be primarily for residential and agricultural uses.

In contrast, the White River floodplain east of Auburn remains predominantly in a forested land cover. From aerial photo interpretation, wetland resources on these alluvial deposits appear to have experienced limited direct human disturbance. Remnant channels, oxbows, and beaver pond systems on small streams on alluvial deposits were observed during photo interpretation in the forested areas of the White River floodplain. While the White River floodplain has limited direct effects to wetland resources, changes in peak flows, base flows, and summer low flows from the Mud Mountain Reservoir and past diversions to Lake Tapps have had indirect effects on these wetland resources.

Alluvial deposits in the Green River valley from east of Auburn to the lower end of the Green River gorge appear to have experienced an intermediate level of human alteration. Dikes and riprap restrict channel movement and decouple the floodplain from the river, while floodplain clearing, wetland drainage, and stream channel straightening alter and degrade wetland resources. While the condition of wetlands within the Green River are not comparable to that of the White River, land use intensity remains low and, because of this, there is good potential to restore wetland resources that can build on the existing wetland and riparian habitats.

Southwest Till Plains

The Southwest Till Plains lithotopo unit is an aggregation of four smaller glacial till plains in the south and western parts of the study area.

Geologic Origin

Quaternary geologic history indicates that the Vashon Stade ice sheet reshaped this lithotopo unit between 13,500 and 15,000 years ago (Luzier 1969, Woodward et al. 1995). Surficial geology of nearly all of this area is glacial till or glacial drift, deposited and compacted by the advancing Vashon ice sheet. Prominent exceptions include a remnant glacial outwash channel filled by lahar deposits, now occupied by Fennel Creek and Lake Tapps, an artificial lake, constructed on glacial till.

Wetland Resource Characterization

The primary factor that differentiates the Southwest Till Plains from the Covington Drift Plain is the lack of recessional outwash within this lithotopo unit. The Southwest Till Plains consist almost exclusively of glacial till and glacial drift. However, we anticipate that wetlands on glacial till or drift have similar form and function in both lithotopo units.

Depressional wetlands dominate in this lithotopo unit and peat systems occur in some depressions. Peat wetlands on glacial till tend to be bogs, characterized by headwater wetlands or wetlands in the upper parts of stream catchments. Under these conditions, precipitation on or near these wetlands tends to dominate hydrologic inputs, resulting in naturally nutrient poor systems that develop Sphagnum peat. Soils data also indicates the presence of depressional wetlands on mineral soils within glacial till. We anticipate that these wetlands have hydrologic inputs dominated by surface water runoff from greater distances, resulting in improved nutrient inputs and greater variability in flow regime. Exceptions to this include a large wetland complex south of Lake Tapps that occupies a remnant glacial outwash channel buried by lahar deposits from the Osceola Mudflow and a few deep depressions on till, west of Auburn, Washington, that appear to be closed systems, having no surface water outlet.

Wetland Data Summarized by Subbasin

Wetland resources in the SR-167 study area were subdivided into 19 subbasins (see Figure 40 in main body of this document) and characterized using data compiled in the potential wetland restoration site dataset. A master wetland data table was developed that groups and summarizes data by subbasin (see Table D-7). A landscape characterization of wetland resources by subbasin follows.

Comparison of Wetland Resources in the Study Area

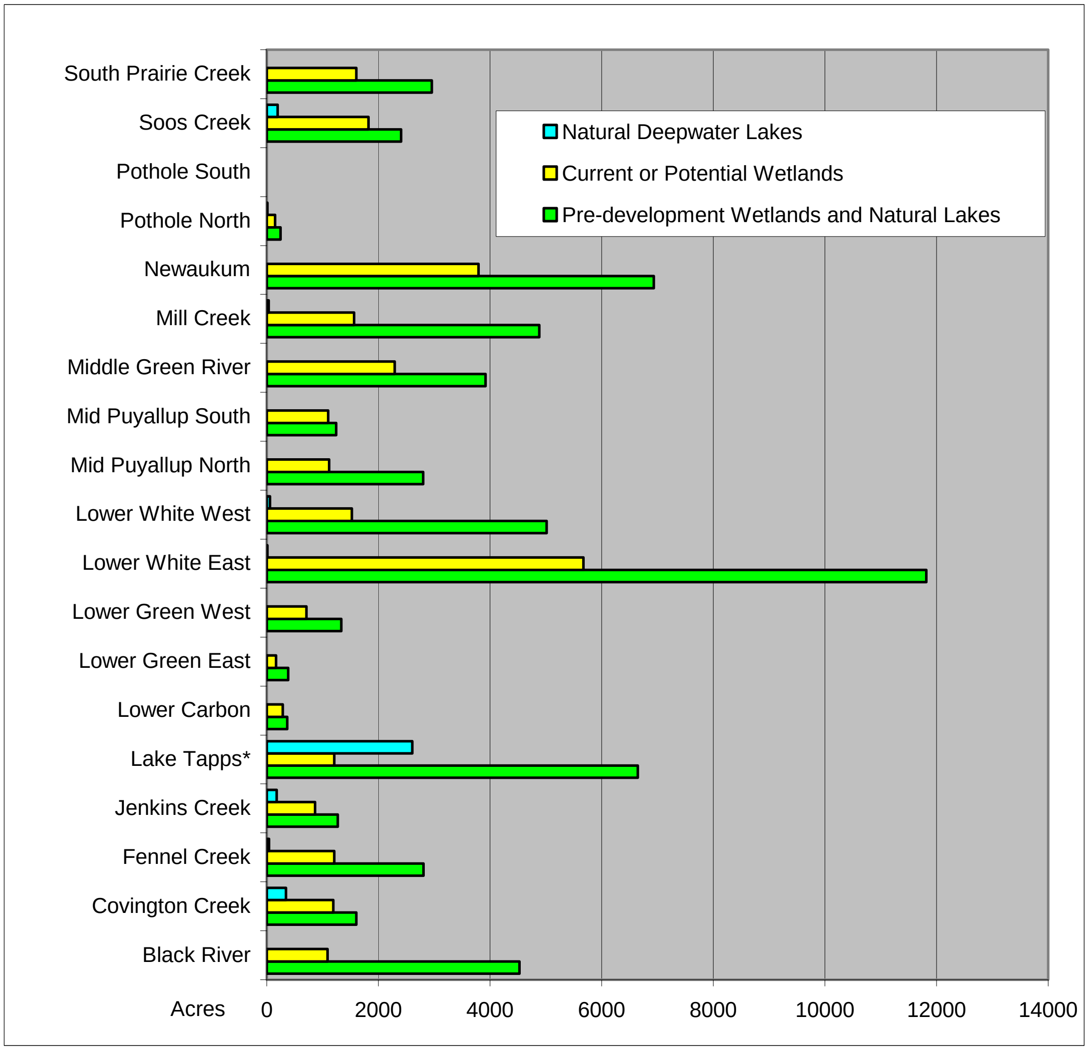
While lithotopo units provide important insight when characterizing wetland resources at landscape scales, local and regional watershed planning efforts use landscape scales that are based on river/stream catchments, rather than topography and geology, to organize and compile data. To facilitate consistency with existing planning efforts, we have subdivided our potential wetland restoration site dataset by subbasin and present a summary of our results.

Predevelopment wetland area by subbasin ranged from a high of 11,806 acres to less than 250 acres (see Figure D-5, Comparison of Pre-development to Current Area of Wetlands and Natural Lakes). Results indicate that seven subbasins had greater than 3,000 acres of predevelopment wetlands. Subbasins with the highest total number of predevelopment wetland acres include the Lower White East (11,806 acres), Newaukum (6,933 acres), Lower White West (4,959 acres), Mill Creek (4,849 acres), Black River (4,527 acres), Lake Tapps (4,040 acres), and Middle Green River (3,917 acres). Subbasins with the lowest total number of predevelopment wetland acres include Pothole South (5 acres), Pothole North (239 acres), Lower Carbon (366 acres) and Lower Green East (386 acres). For more detail, see Table D-7, Status of Wetland Resources by Subbasin.

The proportion of each subbasin in predevelopment wetlands ranged from a high of 57 percent to less than 10 percent. Results indicate that seven subbasins had 30 percent or more of area in predevelopment wetlands. Subbasins with the highest proportion of area in predevelopment wetlands include the Lower White East (57 percent), Lower Green West (50 percent), Mill Creek (50 percent), Newaukum (39 percent), Lake Tapps (37 percent), Fennel Creek (32 percent), and Lower White West (30 percent). For more detail, see Table D-7, Status of Wetland Resources by Subbasin.

Current and potential wetland area by subbasin ranged from a high of 5,672 acres in the Lower White East subbasin less than 200 acres (see Figure D-5, Comparison of Pre-development to Current Area of Wetlands and Natural Lakes). Subbasins estimated to have greater than 2,000 acres of current and potential wetlands include the Lower White East (5,672 acres), Newaukum (3,794 acres), and Middle Green River (2,290 acres). Subbasins estimated to have less than 500 acres of current and potential wetlands include the Pothole South (5 acres), Pothole North (151 acres), Lower Green East (164 acres), and Lower Carbon (285 acres).

When the extent of current and potential wetlands is compared to predevelopment wetland extent, results provide insight into differing levels of land use development and wetland vulnerability. We estimate that that following five subbasins have greater than 67 percent of their predevelopment wetland area remaining as current or potential wetlands: Covington Creek (95 percent), Mid Puyallup South (89 percent), Soos Creek (82 percent), Jenkins Creek (79 percent), and Lower Carbon (78 percent). These five subbasins represent two distinct geographic areas. The Mid Puyallup South and Lower Carbon subbasins are adjacent to each other in the extreme southern part of the study area, while the Covington Creek, Soos Creek, and Jenkins Creek subbasins makeup the larger Soos Creek catchment in the northeastern part of the study area. Subbasins with less than 33 percent of their predevelopment wetland area considered to be in current or potential wetlands include Black River (24 percent), Lake Tapps (30 percent), Lower White West (31 percent), and Mill Creek (32 percent). Three of these four subbasins occur in the shared Lower Green and White River valley, on which nearly all of the SR-167 project area resides.



* Lake Tapps is considered a natural lake for summary purposes

Figure D-5. Comparison of Pre-development to Current Area of Wetlands and Natural Lakes.

A comparison of the proportion of current or potential wetlands in an unaltered condition also reveals important differences by subbasin. Results indicate that subbasins with greater than 50 percent of current or potential wetland acres having little or no evidence of hydrologic or vegetative alteration include Jenkins Creek (70 percent), Covington Creek (58 percent), Lower Carbon (58 percent), and Pothole North (55 percent). Of these subbasins, only two, Jenkins Creek (55 percent) and Covington Creek (55 percent), have greater than 50 percent of all predevelopment wetland acres remaining in an unaltered condition. Subbasins with 20 percent or less of current or potential wetlands having little or no evidence of hydrologic or vegetative alteration include Newaukum (4 percent), Lower Green West (11 percent), Mill Creek (14 percent), Black River (16 percent), and Lake Tapps (20 percent). Further, results indicate that subbasins with 20 percent or less of predevelopment wetland acres having little or no hydrologic or vegetative alteration include Newaukum (2 percent), Black River (4 percent), Mill Creek (5 percent), Lake Tapps (6 percent), Lower Green West (6 percent), Lower White West (9 percent), Mid Puyallup North (11 percent), South

Prairie Creek (12 percent), Fennel Creek (13 percent), and Lower Green East (18 percent). For more detail, see Figure D-6, Comparison of unaltered vs. hydrologically or vegetatively altered wetland acres current or potential by subbasin.

One final comparison relates to differences in the type of wetlands that occur within each subbasin. Photo interpretation, using stereo-paired photos, was used to establish a hydrogeomorphic wetland class (Brinson 1995) for each wetland polygon. Depressional and riverine wetlands represent the dominant wetland classes within the study area. Subbasins having 80 percent or more of all wetland acres in the depressional wetland class under current conditions include Newaukum (94 percent depressional, 6 percent riverine), Mill Creek (91 percent depressional, 4 percent riverine), Lake Tapps (91 percent depressional, 1 percent riverine), Pothole North (89 percent depressional, 9 percent riverine), Soos Creek (88 percent depressional, 11 percent riverine), Lower Green West (83 percent depressional, 17 percent riverine), Black River (83 percent depressional, 15 percent riverine), South Prairie Creek (81 percent depressional, 19 percent riverine), and Covington Creek (80 percent depressional, 18 percent riverine). Subbasins having greater than 55 percent and less than 80 percent in depressional wetland acres under current conditions include Lower Green East (79 percent depressional, 21 percent riverine), Mid Puyallup North (72 percent depressional, 28 percent riverine), Fennel Creek (67 percent depressional, 30 percent riverine), Jenkins Creek (61 percent depressional, 26 percent riverine), and Middle Green River (58 percent depressional, 42 percent riverine). Subbasins having greater than 45 percent of all wetland acres in the riverine wetland class under current conditions include Lower Carbon (2 percent depressional, 96 percent riverine), Mid Puyallup South (44 percent depressional, 56 percent riverine), Lower White West (47 percent depressional, 49 percent riverine), and Lower White East (51 percent depressional, 48 percent riverine).

Human alteration to wetlands can and will have a substantial affect on hydrogeomorphic wetland type, at the time of photo interpretation. For example a depressional wetland that has an effective surface drain will result in the predevelopment depressional wetland being converted to a riverine wetland. Similarly, riverine impounded wetlands that have been decoupled from the river by dikes and development result in the predevelopment riverine wetland being converted to a depressional wetland. The Black River and Mill Creek subbasins are likely examples of areas where human alteration has resulted in a change in hydrogeomorphic wetland type, at the subbasin scale.

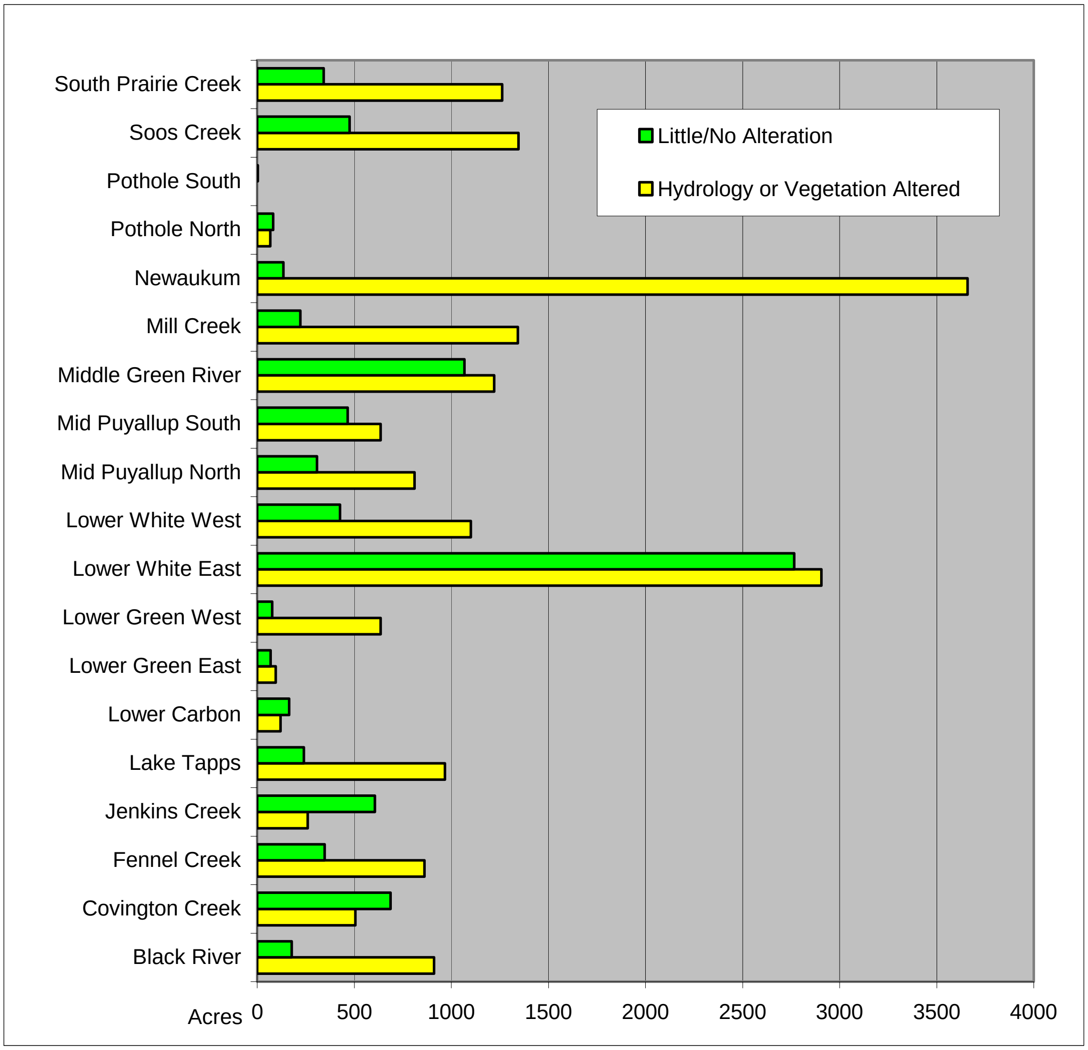


Figure D-6. Comparison of Unaltered vs. Hydrologically or Vegetatively Altered Wetland Acres (current or potential) by Subbasin.

Table D-7. Status of Wetland Resources by Subbasin.

(Under predevelopment conditions and current conditions)

Subbasin	Percent / Area in Predevelopment Wetlands*	Percent / Area in Current or Potential Wetlands**	Current or Potential Wetlands** as Percent of Predevelopment Wetlands*	Percent / Area of Current or Potential Wetlands** with Little or no Alteration	Percent of Predevelopment Wetlands* with Little or no Alteration
Lower White East	57% / 11,806 acres	27% / 5,672 acres	48%	49% / 2,766 acres	23%
Mill Creek	50% / 4,849 acres	16% / 1,566 acres	32%	14% / 223 acres	5%
Lower Green West	50% / 1,334 acres	27% / 713 acres	53%	11% / 77 acres	6%
Newaukum	39% / 6,933 acres	21% / 3,794 acres	55%	4% / 135 acres	2%
Lake Tapps	37% / 4,040 acres	11% / 1,208 acres	30%	20% / 241 acres	6%
Fennel Creek	32% / 2,773 acres	14% / 1,209 acres	44%	29% / 348 acres	13%
Lower White West	30% / 4,959 acres	9% / 1,527 acres	31%	28% / 427 acres	9%
Black River	27% / 4,527 acres	6% / 1,090 acres	24%	16% / 178 acres	4%
South Prairie Creek	23% / 2,955 acres	13% / 1,606 acres	54%	21% / 343 acres	12%
Middle Green River	19% / 3,917 acres	11% / 2,290 acres	59%	47% / 1,068 acres	27%
Mid Puyallup North	16% / 2,800 acres	7% / 1,119 acres	40%	28% / 309 acres	11%

Subbasin	Percent / Area in Predevelopment Wetlands*	Percent / Area in Current or Potential Wetlands**	Current or Potential Wetlands** as Percent of Predevelopment Wetlands*	Percent / Area of Current or Potential Wetlands** with Little or no Alteration	Percent of Predevelopment Wetlands* with Little or no Alteration
Mid Puyallup South	11% / 1,238 acres	10% / 1,102 acres	89%	42% / 467 acres	38%
Soos Creek	11% / 2,215 acres	9% / 1,822 acres	82%	26% / 476 acres	21%
Jenkins Creek	11% / 1,093 acres	8% / 866 acres	79%	70% / 606 acres	55%
Lower Carbon	9% / 366 acres	7% / 285 acres	78%	58% / 165 acres	45%
Pothole North	9% / 239 acres	6% / 151 acres	63%	55% / 83 acres	35%
Covington Creek	9% / 1,260 acres	8% / 1,192 acres	95%	58% / 687 acres	55%
Lower Green East	8% / 386 acres	3% / 164 acres	43%	42% / 69 acres	18%
Pothole South	1% / 5 acres	1% / 5 acres	100%	76% / 4 acres	76%

* Predevelopment wetland estimates are based on hydric soils and current or potential wetland locations; the area of lacustrine wetlands or deepwater lakes has been removed from the dataset used for these calculations.

** Current or potential wetland estimates reflect shallow water wetland data only; the area of lacustrine wetlands or deepwater lakes has been removed from the dataset used for these calculations.

Wetland Narrative by Subbasin

Black River

Prior to human alteration, wetlands in the Black River Subbasin totaled approximately 4527 acres and represented 27 percent of the subbasin. Of this pre-development total, we estimate that all 4527 acres were wetlands. No natural deepwater lakes were noted. We estimate that approximately 1090 acres, or 6 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Twenty-four percent of the original 4527 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 178 acres of wetlands in the Black River Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 16 percent of all existing or potential wetlands (1090 acres) and 4 percent of all historic wetlands (4527 acres). Seventy-six percent (825 acres) of the 1090 acres of current or potential wetlands have evidence of hydrologic alteration, while 71 percent (772 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 911 acres (84 percent) of the 1090 current or potential wetland acres in the Black River Subbasin are considered altered.

Of the 1090 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Black River Subbasin include 909 acres of depressional wetlands (83 percent) and 164 acres of riverine wetlands (15 percent). Anadromous fish are estimated to have access to 48 percent (526 acres) of the 1090 acres of current or potential wetlands in this subbasin.

Covington Creek

Prior to human alteration, wetlands and deepwater lakes in the Covington Creek Subbasin totaled approximately 1605 acres and represented 11 percent of the subbasin. Of this pre-development total, we estimate that 1260 acres (9 percent of subbasin) were wetlands and 345 acres (2 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1192 acres, or 8 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Ninety-five percent of the original 1192 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 687 acres of wetlands in the Covington Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 58 percent of all existing or potential wetlands (1192 acres) and 55 percent of all historic wetlands (1260 acres). Forty-two percent (496 acres) of the 1192 acres of current or potential wetlands have evidence of hydrologic alteration, while 13 percent (154 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 505 acres (42 percent) of the 1192 current or potential wetland acres in the Covington Creek Subbasin are considered altered.

Of the 1192 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Covington Creek Subbasin include 948 acres of depressional wetlands (80 percent) and 211 acres of riverine wetlands (18 percent). Anadromous fish are estimated to have access to 58 percent (883 acres) of the 1537 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Fennel Creek

Prior to human alteration, wetlands and deepwater lakes in the Fennel Creek Subbasin totaled approximately 2810 acres and represented 33 percent of the subbasin. Of this pre-development total, we estimate that 2773 acres (32 percent of subbasin) were wetlands and 37 acres (less that 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1209 acres, or 14 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-four percent of the original 2773 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 348 acres of wetlands in the Fennel Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 29 percent of all existing or potential wetlands (1209 acres) and 13 percent of all historic wetlands (2773 acres). Fifty-seven percent (687 acres) of the 1209 acres of current or potential wetlands have evidence of hydrologic alteration, while 70 percent (844 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 861 acres (71 percent) of the 1209 current or potential wetland acres in the Fennel Creek Subbasin are considered altered.

Of the 1209 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Fennel Creek Subbasin include 809 acres of depressional wetlands (67 percent) and 361 acres of riverine wetlands (30 percent). Anadromous fish are estimated to have access to 2 percent (19 acres) of the 1246 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Jenkins Creek

Prior to human alteration, wetlands and deepwater lakes in the Jenkins Creek Subbasin totaled approximately 1270 acres and represented 13 percent of the subbasin. Of this pre-development total, we estimate that 1093 acres (11 percent of subbasin) were wetlands and 177 acres (2 percent of subbasin) were natural deepwater lakes. We estimate that approximately 866 acres, or 9 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Seventy-nine percent of the original 1093 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 606 acres of wetlands in the Jenkins Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 70 percent of all existing or potential wetlands (866 acres) and 56 percent of all historic wetlands (1093 acres). Twenty-seven percent (234 acres) of the 866 acres of current or potential wetlands have evidence of hydrologic alteration, while 27 percent (236 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 260 acres (30 percent) of the 866 current or potential wetland acres in the Jenkins Creek Subbasin are considered altered.

Of the 866 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Jenkins Creek Subbasin include 526 acres of depressional wetlands (61 percent) and 226 acres of riverine wetlands (26 percent). Anadromous fish are estimated to have access to 48 percent (499 acres) of the 1043 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Lake Tapps

While Lake Tapps is a man-made lake, for our characterization work, we are considering it to be a permanent aquatic feature and include it as a natural deepwater lake system. Prior to human alteration, wetlands and deepwater lakes within the Lake Tapps Subbasin totaled approximately 6646 acres and represented 61 percent of the subbasin. Of this pre-development total, we estimate that 4040 acres (37 percent of subbasin) were wetlands and 2605 acres (24 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1208 acres, or 11 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty percent of the original 4040 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 241 acres of wetlands in the Lake Tapps Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 20 percent of all existing or potential wetlands (1208 acres) and 6 percent of all historic wetlands (4040 acres). Seventy-five percent (903 acres) of the 1208 acres of current or potential wetlands have evidence of hydrologic alteration, while 80 percent (967 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 967 acres (80 percent) of the 1208 current or potential wetland acres in the Lake Tapps Subbasin are considered altered.

Of the 1208 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lake Tapps Subbasin include 1104 acres of depressional wetlands (91 percent) and 9 acres of riverine wetlands (1 percent).

Lower Carbon

Prior to human alteration, wetlands and deepwater lakes in the Lower Carbon Subbasin totaled approximately 366 acres and represented 9 percent of the subbasin. Of this pre-development total, we estimate that all 366 acres were wetlands. No natural deepwater lakes were noted. We estimate that approximately 285 acres, or 7 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Seventy-eight percent of the original 366 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 165 acres of wetlands in the Lower Carbon Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 58 percent of all existing or potential wetlands (285 acres) and 45 percent of all historic wetlands (366 acres). Forty-one percent (117 acres) of the 285 acres of current or potential wetlands have evidence of hydrologic alteration, while 33 percent (95 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 121 acres (42 percent) of the 285 current or potential wetland acres in the Lower Carbon Subbasin are considered altered.

Of the 285 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Carbon Subbasin include 5 acres of depressional wetlands (1 percent) and 275 acres of riverine wetlands (96 percent). Anadromous fish are estimated to have access to 96 percent (274 acres) of the 285 acres of current or potential wetlands in this subbasin.

Lower Green East

Prior to human alteration, wetlands and deepwater lakes in the Lower Green East Subbasin totaled approximately 386 acres and represented 8 percent of the subbasin. Of this pre-development total, we estimate that all 386 acres were wetlands. No natural deepwater lakes were noted. We estimate that approximately 164 acres, or 3 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-three percent of the original 386 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 69 acres of wetlands in the Lower Green East Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 42 percent of all existing or potential wetlands (164 acres) and 18 percent of all historic wetlands (386 acres). Forty-eight percent (79 acres) of the 164 acres of current or potential wetlands have evidence of hydrologic alteration, while 57 percent (93 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 95 acres (58 percent) of the 164 current or potential wetland acres in the Lower Green East Subbasin are considered altered.

Of the 164 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Green East Subbasin include 130 acres of depressional wetlands (79 percent) and 34 acres of riverine wetlands (21 percent). Anadromous fish are estimated to have access to 14 percent (22 acres) of the 164 acres of current or potential wetlands in this subbasin.

Lower Green West

Prior to human alteration, wetlands and deepwater lakes in the Lower Green West Subbasin totaled approximately 1334 acres and represented 50 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 713 acres, or 27 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-three percent of the original 1334 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 77 acres of wetlands in the Lower Green West Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 11 percent of all existing or potential wetlands (713 acres) and 6 percent of all historic wetlands (1334 acres). Eighty-six percent (614 acres) of the 713 acres of current or potential wetlands have evidence of hydrologic alteration, while 89 percent (635 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 635 acres (89 percent) of the 713 current or potential wetland acres in the Lower Green West Subbasin are considered altered.

Of the 713 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Green West Subbasin include 595 acres of depressional wetlands (83 percent) and 118 acres of riverine wetlands (17 percent). Anadromous fish are estimated to have access to 87 percent (622 acres) of the 713 acres of current or potential wetlands in this subbasin.

Lower White East

Prior to human alteration, wetlands and deepwater lakes in the Lower White East Subbasin totaled approximately 11,819 acres and represented 57 percent of the subbasin. Of this pre-development total, we estimate that 11,806 acres (57 percent of subbasin) were wetlands and 13 acres (less than 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 5672 acres, or 27 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-eight percent of the original 11,806 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 2766 acres of wetlands in the Lower White East Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 49 percent of all existing or potential wetlands (5672 acres) and 23 percent of all historic wetlands (11,806 acres). Fifty percent (2841 acres) of the 5672 acres of current or potential wetlands have evidence of hydrologic alteration, while 50 percent (2848 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 2907 acres (51 percent) of the 5672 current or potential wetland acres in the Lower White East Subbasin are considered altered.

Of the 5672 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower White East Subbasin include 2917 acres of depressional wetlands (51 percent) and 2747 acres of riverine wetlands (48 percent). Anadromous fish are estimated to have access to 58 percent (3300 acres) of the 5685 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Lower White West

Prior to human alteration, wetlands and deepwater lakes in the Lower White West Subbasin totaled approximately 5017 acres and represented 31 percent of the subbasin. Of this pre-development total, we estimate that 4959 acres (30 percent of subbasin) were wetlands and 58 acres (less than 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1527 acres, or 9 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty-one percent of the original 4959 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 427 acres of wetlands in the Lower White West Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 28 percent of all existing or potential wetlands (1527 acres) and 9 percent of all historic wetlands (4959 acres). Seventy percent (1067 acres) of the 1527 acres of current or potential wetlands have evidence of hydrologic alteration, while 62 percent (942 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1100 acres (72 percent) of the 1527 current or potential wetland acres in the Lower White West Subbasin are considered altered.

Of the 1527 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower White West Subbasin include 723 acres of depressional wetlands (47 percent) and 749 acres of riverine wetlands (49 percent). Anadromous fish are estimated to have access to 33 percent (519 acres) of the 1585 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Mid Puyallup North

Prior to human alteration, wetlands and deepwater lakes in the Mid Puyallup North Subbasin totaled approximately 2800 acres and represented 16 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 1119 acres, or 7 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty percent of the original 2800 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 309 acres of wetlands in the Mid Puyallup North Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 28 percent of all existing or potential wetlands (1119 acres) and 11 percent of all historic wetlands (2800 acres). Sixty-five percent (732 acres) of the 1119 acres of current or potential wetlands have evidence of hydrologic alteration, while 58 percent (644 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 810 acres (72 percent) of the 1119 current or potential wetland acres in the Mid Puyallup North Subbasin are considered altered.

Of the 1119 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mid Puyallup North Subbasin include 805 acres of depressional wetlands (72 percent) and 314 acres of riverine wetlands (28 percent). Anadromous fish are estimated to have access to 25 percent (279 acres) of the 1119 acres of current or potential wetlands in this subbasin.

Mid Puyallup South

Prior to human alteration, wetlands and deepwater lakes in the Mid Puyallup South Subbasin totaled approximately 1246 acres and represented 11 percent of the subbasin. Of this pre-development total, we estimate that 1238 acres (11 percent of subbasin) were wetlands and 7 acres (less than 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1102 acres, or 10 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Eighty-nine percent of the original 1238 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 467 acres of wetlands in the Mid Puyallup South Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 42 percent of all existing or potential wetlands (1102 acres) and 38 percent of all historic wetlands (1238 acres). Fifty-seven percent (624 acres) of the 1102 acres of current or potential wetlands have evidence of hydrologic alteration, while 43 percent (473 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 635 acres (58 percent) of the 1102 current or potential wetland acres in the Mid Puyallup South Subbasin are considered altered.

Of the 1102 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mid Puyallup South Subbasin include 482 acres of depressional wetlands (44 percent) and 616 acres of riverine wetlands (56 percent). Anadromous fish are estimated to have access to 43 percent (474 acres) of the 1109 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Middle Green River

Prior to human alteration, wetlands and deepwater lakes in the Middle Green River Subbasin totaled approximately 3917 acres and represented 19 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 2290 acres, or 11 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-nine percent of the original 3917 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 1068 acres of wetlands in the Middle Green River Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 47 percent of all existing or potential wetlands (2290 acres) and 27 percent of all historic wetlands (3917 acres). Forty-six percent (1048 acres) of the 2290 acres of current or potential wetlands have evidence of hydrologic alteration, while 50 percent (1155 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1222 acres (53 percent) of the 2290 current or potential wetland acres in the Middle Green River Subbasin are considered altered.

Of the 2290 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Middle Green River Subbasin include 1337 acres of depressional wetlands (58 percent) and 953 acres of riverine wetlands (42 percent). Anadromous fish are estimated to have access to 38 percent (870 acres) of the 2290 acres of current or potential wetlands in this subbasin.

Mill Creek

Prior to human alteration, wetlands and deepwater lakes in the Mill Creek Subbasin totaled approximately 4881 acres and represented 50 percent of the subbasin. Of this pre-development total, we estimate that 4849 acres (50 percent of subbasin) were wetlands and 32 acres (less than 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1566 acres, or 16 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty-two percent of the original 4849 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 223 acres of wetlands in the Mill Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 14 percent of all existing or potential wetlands (1566 acres) and 5 percent of all historic wetlands (4849 acres). Eighty-five percent (1337 acres) of the 1566 acres of current or potential wetlands have evidence of hydrologic alteration, while 84 percent (1312 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1343 acres (86 percent) of the 1566 current or potential wetland acres in the Mill Creek Subbasin are considered altered.

Of the 1566 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mill Creek Subbasin include 1420 acres of depressional wetlands (91 percent) and 65 acres of riverine wetlands (4 percent). Anadromous fish are estimated to have access to 37 percent (588 acres) of the 1597 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Newaukum Creek

Prior to human alteration, wetlands and deepwater lakes in the Newaukum Creek Subbasin totaled approximately 6933 acres and represented 39 percent of the subbasin. Of this pre-development total, we estimate that all 6933 acres were wetlands. No natural deepwater lakes were noted in this subbasin. We estimate that approximately 3794 acres, or 21 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-five percent of the original 6933 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 135 acres of wetlands in the Newaukum Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 4 percent of all existing or potential wetlands (3794 acres) and 2 percent of all historic wetlands (6933 acres). Ninety-five percent (3606 acres) of the 3794 acres of current or potential wetlands have evidence of hydrologic alteration, while 95 percent (3604 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 3658 acres (96 percent) of the 3794 current or potential wetland acres in the Newaukum Creek Subbasin are considered altered.

Of the 3794 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Newaukum Creek Subbasin include 3579 acres of depressional wetlands (94 percent) and 215 acres of riverine wetlands (6 percent). Anadromous fish are estimated to have access to 46 percent (1742 acres) of the 3794 acres of current or potential wetlands in this subbasin.

Pothole

Pothole North: Prior to human alteration, wetlands and deepwater lakes in the northern piece of the Pothole Subbasin totaled approximately 248 acres and represented 9 percent of the subbasin. Of this pre-development total, we estimate that 239 acres (9 percent of subbasin) were wetlands and 9 acres (less than 1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 151 acres, or 6 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Sixty-three percent of the original 239 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 83 acres of wetlands in the northern piece of the Pothole Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 55 percent of all existing or potential wetlands (151 acres) and 35 percent of all historic wetlands (239 acres). Thirty-three percent (49 acres) of the 151 acres of current or potential wetlands have evidence of hydrologic alteration, while 39 percent (59 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 68 acres (45 percent) of the 151 current or potential wetland acres in the subbasin are considered altered.

Of the 151 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the northern piece of the Pothole Subbasin include 135 acres of depressional wetlands (89 percent) and 14 acres of riverine wetlands (9 percent). Based on the landscape position of fish-bearing streams in relation to the 160 acres of natural deepwater lakes and current or potential wetlands in this subbasin, we estimate that no existing/potential lake or wetland sites are accessible to anadromous fish.

Pothole South: Prior to human alteration, wetlands and deepwater lakes in the southern piece of the Pothole Subbasin totaled approximately 5 acres and represented 1 percent of the subbasin. Of this pre-development total, we estimate that all 5 acres were wetlands. No natural deepwater lakes were identified in the subbasin. We estimate that approximately 5 acres, or 1 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. All of the original 5 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 4 acres of wetlands in the southern piece of the Pothole Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 76 percent of all existing or potential wetlands (5 acres) and 76 percent of all historic wetlands (5 acres). Twenty-four percent (1 acre) of the 5 acres of current or potential wetlands have evidence of hydrologic alteration. No evidence of vegetative alteration was observed. When both hydrologic and vegetative alterations are considered together, 1 acre (24 percent) of the 5 current or potential wetland acres in the subbasin are considered altered.

Of the 5 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the southern piece of the Pothole Subbasin include 5 acres of depressional wetlands (100 percent). Based on the landscape position of fish-bearing streams in relation to the 160 acres of natural deepwater lakes and current or potential wetlands in this subbasin, we estimate that no existing/potential lake or wetland sites are accessible to anadromous fish.

Soos Creek

Prior to human alteration, wetlands and deepwater lakes in the Soos Creek Subbasin totaled approximately 2407 acres and represented 12 percent of the subbasin. Of this pre-development total, we estimate that 2215 acres (11 percent of subbasin) were wetlands and 192 acres (1 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1822 acres, or 9 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Eighty-two percent of the original 2215 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 476 acres of wetlands in the Soos Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 26 percent of all existing or potential wetlands (1822 acres) and 21 percent of all historic wetlands (2215 acres). Sixty-three percent (1153 acres) of the 1822 acres of current or potential wetlands have evidence of hydrologic alteration, while 74 percent (1341 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1346 acres (74 percent) of the 1822 current or potential wetland acres in the Soos Creek Subbasin are considered altered.

Of the 1822 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Soos Creek Subbasin include 1611 acres of depressional wetlands (88 percent) and 206 acres of riverine wetlands (11 percent). Anadromous fish are estimated to have access to 48 percent (962 acres) of the 2014 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

South Prairie Creek

Prior to human alteration, wetlands and deepwater lakes in the South Prairie Creek Subbasin totaled approximately 2955 acres and represented 23 percent of the subbasin. Of this pre-development total, we estimate that all 2955 acres were wetlands. No natural deepwater lakes were noted in this subbasin. We estimate that approximately 1606 acres, or 13 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-four percent of the original 2955 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 343 acres of wetlands in the South Prairie Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 21 percent of all existing or potential wetlands (1606 acres) and 12 percent of all historic wetlands (2955 acres). Seventy-five percent (1209 acres) of the 1606 acres of current or potential wetlands have evidence of hydrologic alteration, while 78 percent (1260 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1262 acres (79 percent) of the 1606 current or potential wetland acres in the South Prairie Creek Subbasin are considered altered.

Of the 1606 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the South Prairie Creek Subbasin include 1296 acres of depressional wetlands (81 percent) and 299 acres of riverine wetlands (19 percent). Anadromous fish are estimated to have access to 50 percent (798 acres) of the 1606 acres of current or potential wetlands in this subbasin.

Wetland Data Summarized by Drainage Analysis Unit

Wetland resources in the SR-167 study area were sub-divided into 238 drainage analysis units (see Figure 41 in main body of this document). We developed a master wetland data table that groups and summarizes key data by Drainage Analysis Unit which is available on CD by request.

Characterization of Floodplain Resources within the SR-167 Study Area

Characterization of Riparian Resources within the SR-167 Study Area

Riparian areas are an important natural resource, influencing how water, sediment, nutrients, and large wood are delivered to and routed through a stream system. We identified and assessed the condition of stream riparian areas within the SR-167 study area to serve as a tool for characterizing key ecological processes and to identify potential mitigation opportunities.

Methods

We created an ArcMap data layer to which we compiled data on potential riparian restoration sites within the study area. Available data used to assess riparian condition include DNR 1:24,000 hydrography, 2002 orthophotos, and color stereo-paired aerial photos taken in July, August, and September of 2001.

We established 33-meter and 67-meter stream buffers using DNR hydrography. The 33-meter buffer provides insight into the condition of the riparian system and its ability to provide stream shading for temperature attenuation and corresponds with local government agencies 100-foot buffer for planning under local critical areas ordinances. The condition of the 67-meter buffer is used to provide an understanding of forest connectivity, water quality and quantity benefits, and potential for recruiting large woody debris (LWD) and is based roughly on site-potential tree height.

Non-forest areas within the riparian buffers were delineated using GIS and both orthophotos and color stereo-paired aerial photographs. Following methods described in Gersib et al. (2004), we created a polygon and a corresponding database file for each non-forested riparian area. For each polygon established, we determined potential for riparian restoration based on current land use, potential to add to an existing forest patch, potential to reconnect two fragmented forest patches, presence of C or D soils, and adjacency to schools and public lands.

Non-natural, non-forested areas included developed land, fields, shrub lands, golf courses, cemeteries, aqueducts, powerline corridors, parks, bare earth, and gravel pits. Natural, forested areas included wetlands and clear-cuts in the process of reforestation. Greater than 65% forest cover in a landscape was given a designation of "Properly Functioning," 50-65% were considered "At Risk," and any landscape with less than 50% forest cover became "Not Properly Functioning" (Gersib et al. 2004). A map of forested and non-forested land per stream catchment was created for comparison, which is included in the main body of this document as Figure 47, Condition of Riparian Systems by Subbasin.

Potential riparian areas overlapping existing or potential wetlands were deleted from the dataset. These sites occurred when wetlands were drained and the drain currently functions as a stream or when non-forested emergent wetlands occurred. The reforestation of this artificial riparian area has potential to preclude restoration of the historic natural resource, or degrade properly functioning wetlands, and should be avoided. Remaining potential riparian restoration sites were then screened by size, with sites less than three acres deleted from the dataset.

In general, the riparian forest in the study area has been heavily impacted by human development, and almost 50% of its forest removed. The valley subbasins have the most extensive riparian forest loss, including the Black River, Lower Green West, Mill Creek, and Pothole Subbasins (Table D-8, Total Riparian Acreage and Current Riparian Forest Cover Acreage, and Figure D-7, Total Riparian Acreage and Current Riparian Forest Cover Acreage).

Results

The potential riparian restoration ArcMap data layer is available on a CD on request.

Table D-8. Total Riparian Acreage and Current Riparian Forest Cover Acreage.

Subbasin	Total Acres of Forest in the Riparian Zone	Total Acres in the Riparian Zone	Percent Forest Cover in the Riparian Zone
Black River	646	2,508	25.8%
Covington Creek	1,270	2,197	57.8%
Fennel Creek	360	736	49.0%
Jenkins Creek	655	1,106	59.2%
Lake Tapps	384	686	55.9%
Lower Carbon	532	642	82.8%
Lower Green East	396	579	68.3%
Lower Green West	212	747	28.4%
Lower White East	1,839	2,938	62.6%
Lower White West	1,390	2,862	48.6%
Mid Puyallup North	1,314	2,714	48.4%
Mid Puyallup South	999	1,451	68.8%
Middle Green River	2,633	3,569	73.8%
Mill Creek	295	1,273	23.1%
Newaukum	1,529	2,617	58.4%
Pothole Subbasin	62	230	26.8%
Soos Creek	1,196	2,566	46.6%
South Prairie Creek	1,158	1,573	73.6%
TOTAL	**16,871**	**30,995**	54.4%

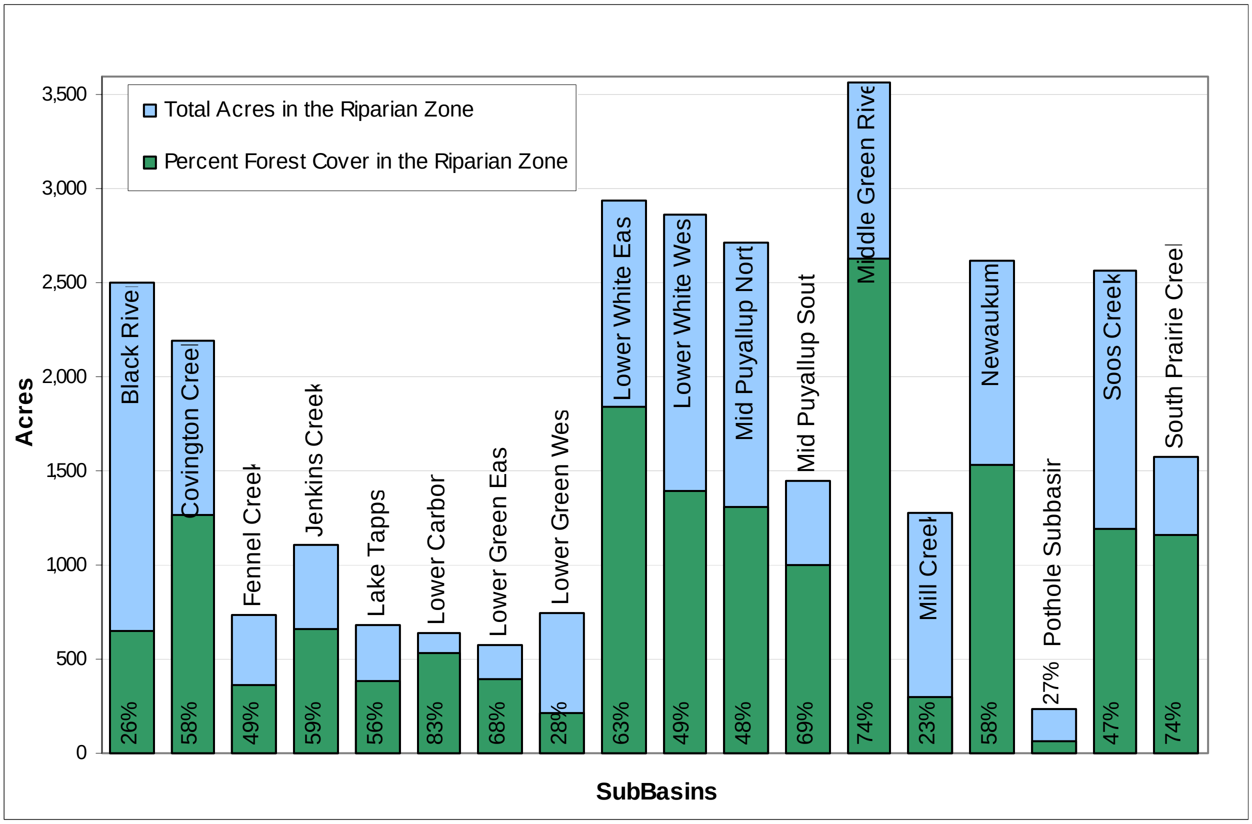


Figure D-7. Total Riparian Acreage and Current Riparian Forest Cover Acreage.

Characterization of Upland Forest Cover within the SR-167 Study Area

Purpose

Following the methods outlined in the Operational Draft Methods Document, Part 1, Step 4 (Gersib et al. 2004), we addressed forest connectivity at both the landscape- and site-scale throughout the watershed, examining areas of varying levels of forest density in the study area, and identifying patches that serve as stepping-stones between aggregated forest patches for different levels of species vagility. The forest density areas will help describe the general condition of forest cover in the study area, defining ecological process scores at a landscape-scale. The stepping-stone patches may add to the individual importance of potential riparian, wetland, and floodplain mitigation or restoration sites, indicating their possible contribution to forest connectivity.

Historically, the dominant vegetative type for the Puget Sound Lowlands in the SR 167 study area was coniferous forest with areas of deciduous forest on the floodplain and a few oak prairies on the southwest portion of the study area (Pojar and MacKinnon 1994). Due to the occasional natural disaster, disease, flooding, fire, windstorms, earthquakes, or volcanic outbursts, the forests were composed of a patchwork of varying ages and species of vegetation. Human effects on the forest cover, including extensive urbanization, road building, logging, ranching, farming, fire suppression, introduction of non-native species, and flood reduction by the creation of dams and channelization of the rivers since the early 1900's, has significantly reduced the extent and composition of historical forests (Stein 2001). Remaining forested areas have become disconnected, fragmented by human development.

Methods

The data on forest cover for the SR 167 study area was derived from 1998 Landsat satellite imagery (Figure 58, Upland Forest Cover, in main body of this document). According to the urban land cover classification of Landsat satellite imagery by Hill et al. (2003), forest is defined as 70% forest cover within the 30-meter grain size, with accuracy between 86-98%. The Landsat metadata has no further detail on the type of forest, species composition or age represented by the designation 'forest,' so, unfortunately, we cannot infer more species-specific information on the suitability of the forest as habitat, without further site-scale studies that are beyond the scope of this project.

To explore the proportion and distribution of forest in the study area, we used FRAGSTATS, a free program developed by McGarigal et al. (2002), to compute landscape metrics (Table D-9, FRAGSTATS landscape metric descriptions). As mentioned before, the data for forest, non-forest, and water land cover was derived from 1998, 30-meter^2 resolution, classified Landsat satellite imagery. Discrepancies with land use change in the intervening years must be taken into consideration. Following the technique laid out in the methods section, we ran the appropriate metrics for both the landscape and the site-scale analysis (Gersib et al., 2004).

Landscape-level

To facilitate our selection of mitigation sites, we examined forested patches at a landscape scale to target medium-density forested areas that were 'At Risk' for forest connectivity, following the approach outlined in the Methods section. In addition to a visual interpretation of the densities, we calculated the following landscape metrics to determine the ecological condition ratings for forest cover.

Table D-9. FRAGSTATS landscape metric descriptions.

Metric	Name	Description
AREA	Patch Area	Area of each patch (ha)
TA	Total Area	Total landscape area (ha)
CA	Class Area	Total class area within a landscape (ha)
PLAND	Percent of Landscape	Percentage of landscape in class (%)
NP	Number of Patches	Total number of patches in the class
LPI	Largest Patch Index	Percentage of the landscape comprised by the largest patch
GYRATE_AM	Area-weighted Mean Radius of Gyration	The area-weighted mean radius of gyration: correlation length, the average distance (m) traversed from a random starting point in a random direction with in a landscape, its traversability
COHESION	Patch Cohesion Index	Physical connectedness of patches in a class, approaches 0 as class becomes less aggregated (comparative value, see Methods)
PROX	Proximity Index	Considers the size and proximity of all patches whose edges are within a specified search radius of the focal patch (comparative value)

After McGarigal et al. 2002

Total Area (TA) and Class Area (CA) were used in conjunction with the Percent of Landscape in forest (PLAND) to examine the forest density for comparison per landscape. A low number of patches (NP) with a high PLAND score usually correlated with a high Largest Patch Index (LPI), indicating that a few large, contiguous forest patches were covering the landscape, contributing to a high connectivity score. For instance, in the Carbon Heights forest density area there are only 62 patches, covering 80% of the landscape, with the largest patch comprising 76% of the landscape, indicating a high-density forest distribution with the possibility of high structural connectivity. In contrast, the Green Valley forest density area has 1,518 patches, covering only 9% of the landscape, with the largest patch comprising 0.4% of the landscape, indicating low-density, scattered forest distribution with a very low possibility of structural connectivity (Table D-10. FRAGSTATS-calculated landscape metrics).

We categorized the forest density areas into high, medium, and low density to establish ecological benefit scores. Mitigation sites within “At Risk” areas were given a higher ecological benefit score than those in “Properly Functioning” or “Not Properly Functioning” areas. In this study area, the largest patch in the Green Covington forest density area has a relatively high PLAND score, a high COHESION score, and the largest GYRATE_AM score, but its LPI is much lower than the Carbon Heights score (Table D-10, FRAGSTATS-calculated landscape metrics). This comparison can be seen more graphically in Figure D-8. Patch Cohesion Index (COHESION) by the percent of landscape in forest (PLAND) for forest density areas). The Green Covington area is large, the patches fairly connected, but there are enough white, developed spaces to slide this forest density area into an “At Risk” category. Carbon Heights, on the other hand, has a high score for all metrics, indicating its high forest connectivity, high density and high probability of supporting habitat connectivity, imparting a “Properly Functioning” designation. In contrast, portions of the study area down in the Green River Valley have been heavily developed, their forest patches fragmented, and with low scores for all landscape metrics, they are categorized as “Not Properly Functioning” for forest connectivity, with a low probability of supporting habitat connectivity. For a greater level of detail, see Table D-10. FRAGSTATS-calculated landscape metrics for forest density area ratings, and Table D-11, Final Condition Score for forest density areas. Also see Figure 59 (in main body of the document), Final Condition Map for Forest Density Areas).

Table D-10. FRAGSTATS-calculated landscape metrics for forest density area ratings.

Converted from metric to English units (McGarigal et al. 2002).

Forest Density Areas	TA (acres)	CA (acres)	PLAND (%)	NP	LPI (%)	GYRATE_AM (ft)	COHESION
Carbon Heights	8,137	6,509	80.0	62	76.2	6,746	99.89
Green Covington	34,041	20,533	60.3	676	46.9	12,780	99.84
Green Highlands	8,888	2,583	29.1	477	6.2	1,759	94.62
Green Valley	41,634	3,772	9.1	1518	0.4	544	85.94
Jenkins Soos	28,297	5,612	19.8	1360	2.6	1,502	94.30
Lake Tapps Fennel	26,213	5,439	20.7	643	2.9	1,548	95.52
Mid Puyallup Highlands	9,333	5,316	57.0	183	44.7	8,943	99.68
Mid Puyallup North	3,757	672	17.9	209	4.9	738	92.24
Newaukum Highlands	4,671	3,673	78.6	28	76.1	5,507	99.86
Newaukum Plateau	23,468	3,204	13.7	901	0.6	737	90.57

Forest Density Areas	TA (acres)	CA (acres)	PLAND (%)	NP	LPI (%)	GYRATE_AM (ft)	COHESION
Soos Lake Youngs	11,684	5,573	47.7	330	31.3	5,468	99.36
South Prairie	8,507	4,985	58.6	163	54.4	8,470	99.84
White River	13,573	8,112	59.8	276	34.2	7,886	99.36

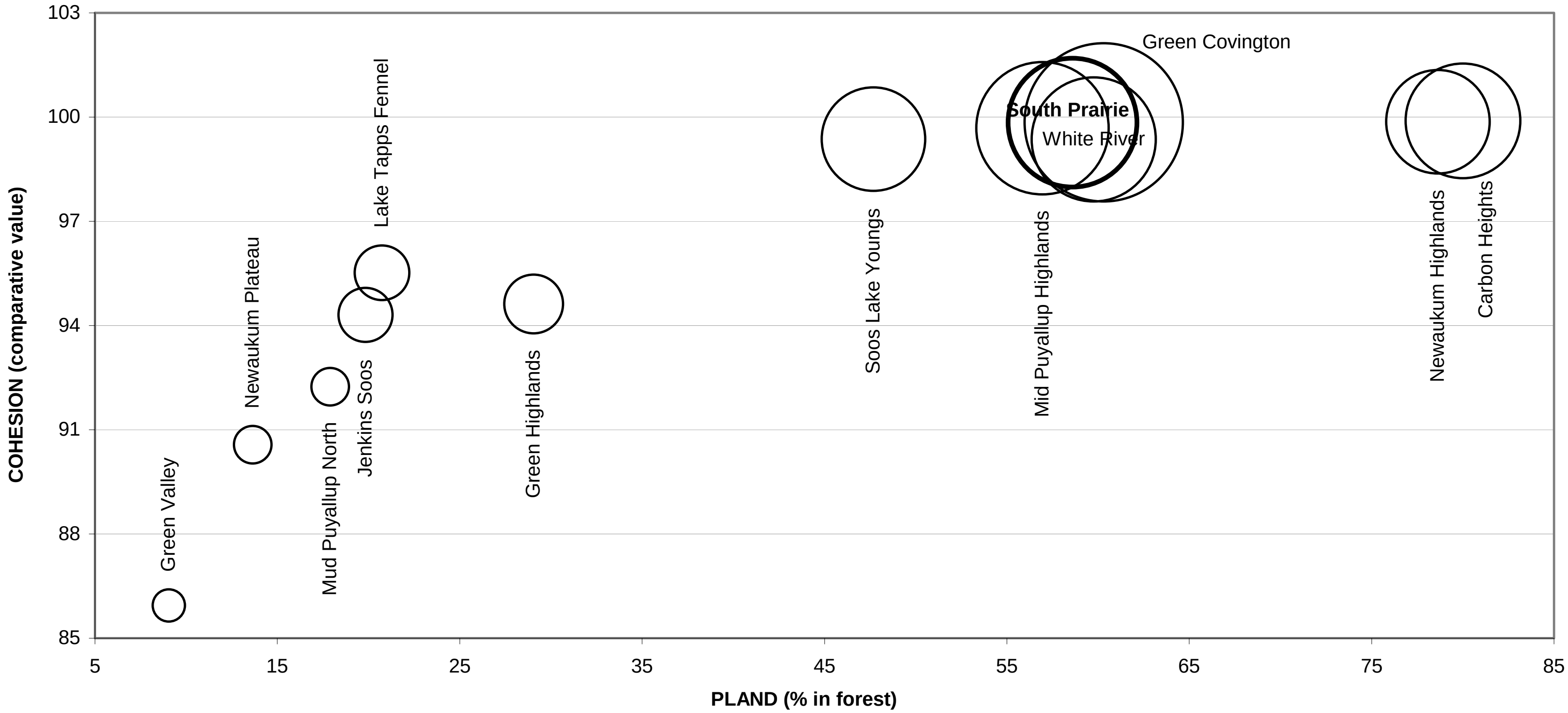


Figure D-8. Patch Cohesion Index by the percent of landscape in forest for forest density areas.

Weighted by the area-weighted mean radius of gyration.

Table D-11. Final condition score for forest density areas.

Forest Density Area	Forest Density Condition
Carbon Heights	Properly Functioning
Green Covington	At Risk
Green Highlands	Not Properly Functioning
Green Valley	Not Properly Functioning
Lake Tapps Fennel	Not Properly Functioning
Jenkins Soos	Not Properly Functioning
Mid Puyallup Highlands	At Risk
Mid Puyallup North	Not Properly Functioning
Newaukum Highlands	Properly Functioning
Newaukum Plateau	Not Properly Functioning
Soos Lake Youngs	At Risk
South Prairie	At Risk
White River	At Risk

In general, the study area contains remaining forest patch concentrations along hill slopes and river canyons. The Green/Puyallup/White river valley is focused on industrial and urbanized land use, the Enumclaw Plateau on farming, and the northeastern section of the study area in widely spaced, yet within the areas tightly clustered, housing developments. Forest density has been heavily affected by these human land uses.

Site-level

For the site-scale level of analysis, we are looking for patches that have the highest probability of contributing to forest-patch connectivity, and possible habitat connectivity. These are the stepping-stone patches; those that are in close proximity to larger patches and could contribute to a network of interconnected forest patches. Potential mitigation sites that are near these stepping-stone patches may add to their size, reinforcing the existing forest patches and increasing their ability to contribute to forest-patch connectivity.

Using the procedures described in the methods portion of this document, we compared the proximity values for each proximity buffer to determine the highest-ranking patches for forest connectivity.

For this study area, with a cell-size of 30-m^2, we used a low proximity buffer of 60-meters, or one cell distance between two patches. The low buffer size corresponds to species with low vagility, such as the Townsend's Vole, Bushy-tailed Woodrat, Townsend's Mole, Long-eared Owl, and Ensatina. For the medium proximity buffer, 400-meters includes the movements of species such as the Song Sparrow, Bullfrog, Deer Mouse, Coast Mole, California Ground Squirrel, Anna's Hummingbird, Pacific Chorus (Tree) Frog, Black-capped Chickadee, Mountain Beaver, and Rough-skinned Newt. To encompass high-mobility species, we used a high proximity buffer of 8,000-meters, corresponding to approximately five miles, which is the average range of such animals as the Masked Shrew, Striped Skunk, Bushtit, Northwestern Salamander, Wood Duck, Pacific Giant Salamander, Red-tailed Hawk, American Beaver, Western Pond Turtle, Common Porcupine, Black-tailed Deer, and Vaux's Swift (selected species based on seasonal movement and the distance between natal area and first breeding site from O'Neil et al. 2001). We must emphasize, here, that we do not know the specific distributions of these species, only their likelihood of existing in this area. We cannot infer functional landscape connectivity within the study area, only the possibility of structural connectivity based on dispersal ability.

We created shapefiles of the highest PROX values for each proximity buffer, based on a histogram of the values: 60-m (19,660-12,310), 400-m (19,759-12,310), and 8,000-m (19,766-12,311). In general, the patches with high proximity values for each proximity buffer overlapped each other, surrounding much larger, well-connected patches. There is a strong possibility that these patches will contribute to structural connectivity for a generalist species with a wide vagility and a dependence on forest cover as defined by the historical, native landcover for this area.

Caveats

There are a few caveats to consider when interpreting the data from this analysis, as noted in the general Methods section. It must be taken into account that the Landsat satellite photos were taken in 1998, and there may be significant change in forest cover in the intervening years. At the time of the study the Landsat data was the most current classified land cover available.

The Proximity Index targets those areas near the largest patches, the first stepping-stone, but it does not capture a series of stepping-stones between major patches. The viability of one forest patch as a stepping-stone is dependant on the condition of the nearest major forest patch, and the next stepping-stones along the line between major patches are even more sensitive to changes in their neighbor's condition.

Overall, there is a *possibility* that improving or expanding forested areas will contribute to forest structural connectivity, and that it will in turn contribute to functional or habitat connectivity for a species of concern. Without species-specific information about the area or more detailed land cover analysis, however, we cannot infer landscape, habitat, or functional connectivity for the study area (Tischendorf and Fahrig 2000).

This is, nevertheless, a step in the right direction to addressing biological components when considering transportation mitigation opportunities. We compared areas of forest density for the overall condition of the study area, adding to natural resource scores where sites fell within "at risk" areas. We also developed a forest patch comparison between the potential wetland, riparian, and floodplain mitigation sites and the steeping-stones for each proximity buffer, considering only the highest PROX scores for each buffer. Potential mitigation sites that are in close proximity to the stepping-stone patches were given an ecological benefit point, used when sifting the sites for priority ranking.

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